Lodz University of Technology
Institute of Electrical Power Engineering

SIGNAL PARAMETERS IDENTIFICATION METHODS USED IN WIDE-AREA MEASUREMENT SYSTEMS

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PLAN PRESENTATION

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INTRODUCTION

The accuracy of phasor parameters estimation is described by the Total Vector Error (TVE). For a particular instant of time the TVE equals:

$$TVE(n) = \sqrt{\frac{\left(\hat{X}_r(n) - X_r(n)\right)^2 + \left(\hat{X}_i(n) - X_i(n)\right)^2}{(X_r(n))^2 + (X_i(n))^2}}$$

where:

$\hat{X}_r(n)$, $\hat{X}_i(n)$ – real and imaginary sequences of estimates given by the PMU under test at a particular instant of time,

$X\ (n)$, $X\ (n)$ – real and imaginary sequences of theoretical values of the input signal at a particular instant of time.

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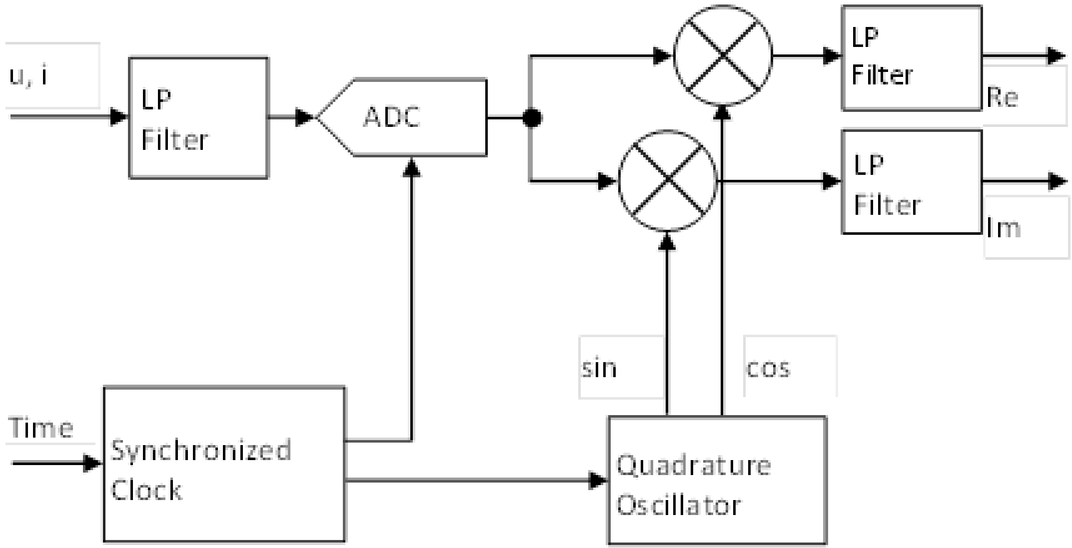
QUADRATURE FILTERS



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QUADRATURE FILTERS

Considering a set of samples for one signal phase $x_{(i)}$, the synchrophasor estimate $X_{(i)}$ is as follows:

$$X(i) = \frac{\sqrt{2}}{Gain} \times \sum_{k=-\frac{N}{2}}^{k=\frac{N}{2}} x_{(i+k)} \times W_{(k)} \times exp(-j(i+k)\Delta t \omega_0)$$

$$Gain = \sum_{k=-\frac{N}{2}}^{k=\frac{N}{2}} W_{(k)}$$

where:

$W_{(k)}$ – coefficients of the low-pass filter for P or M class,

N – filter order,

Δt – 1/sampling frequency,

ω_0 – the nominal power system frequency equal 50 Hz or 60 Hz.

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QUADRATURE FILTERS

Coefficients $W_{(k)}$ of the class P filter can be obtained from:

$$W_{(k)} = \left(1 - \frac{2}{N+2}|k|\right)$$

where:

N– filter order equals $N = (15-1) \times 2 = 28$, k– integer values within $-\frac{N}{2} : \frac{N}{2}$.

The class M filter coefficients are obtained by means of:

$$W(k) = \frac{sin\left(2\pi\times\frac{2F_{\text{fr}}}{F_{\text{sampling}}}\times k\right)}{2\pi\times\frac{2F_{\text{fr}}}{F_{\text{sampling}}}\times k} h(k)$$

where:

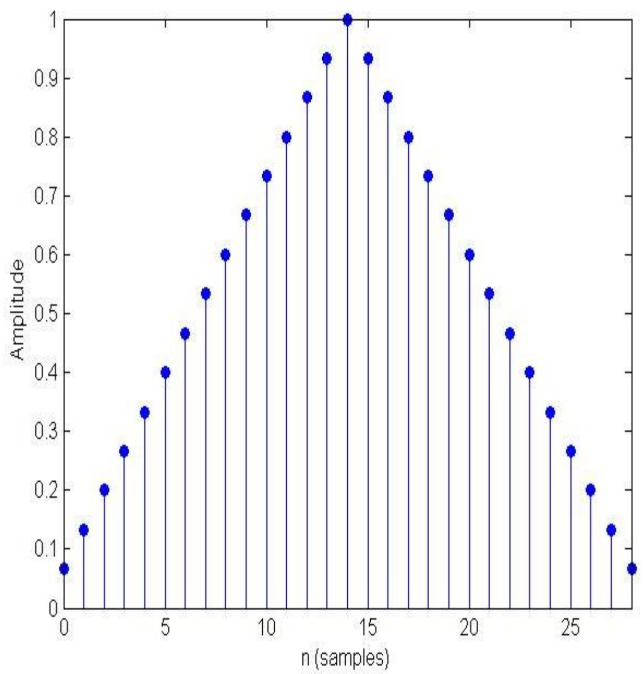
N– filter order (the filter order is $N = 142$),

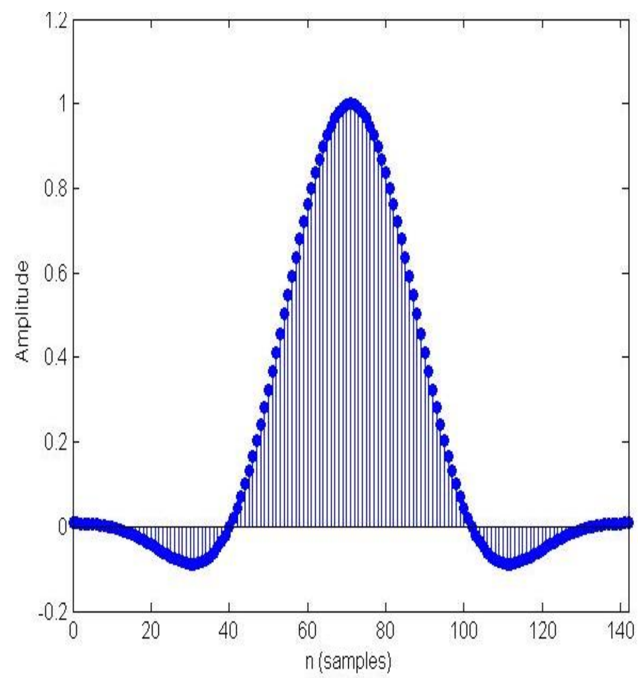
F_{fr} – the reference frequency of a low-pass filter ($F_{\text{fr}} = 7{,}75$ Hz),

F_{sampling} – sampling frequency of the system (960 samples per second),

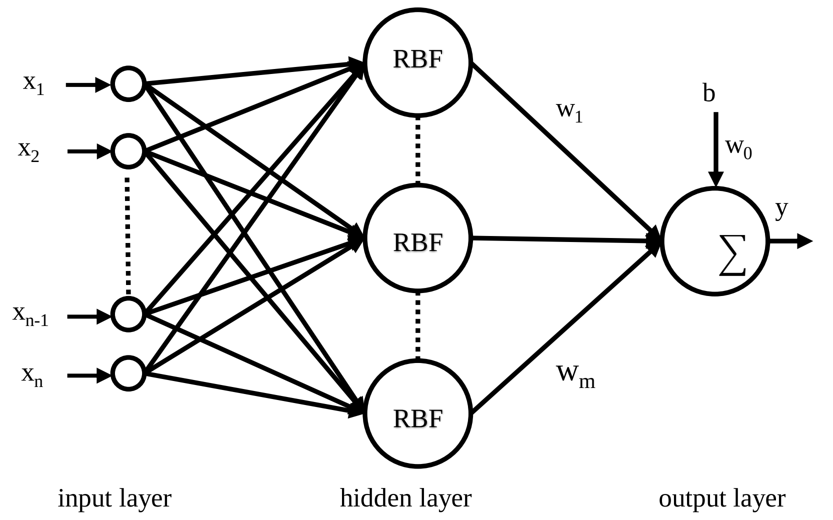
$h(k)$ – Hamming function.

QUADRATURE FILTERS





RADIAL ARTIFICIALİ NEURAL NETWORK



CALCULATION RESULTS

The conducted tests used input functions described in Standards and were carried out by means of three methods:

- class P quadrature filters,
- class M quadrature filters,
- a radial artificial neural network.

TVE values for steady-state functions including:

- an ideal signal (function 1),
- a signal frequency between 48 Hz – 52 Hz (functions 2 – 5),
- a signal with a varied magnitude between 0.1 – 1.2 (functions 6-9)
- a signal with higher harmonics from 2nd to 50th (functions 10-58).

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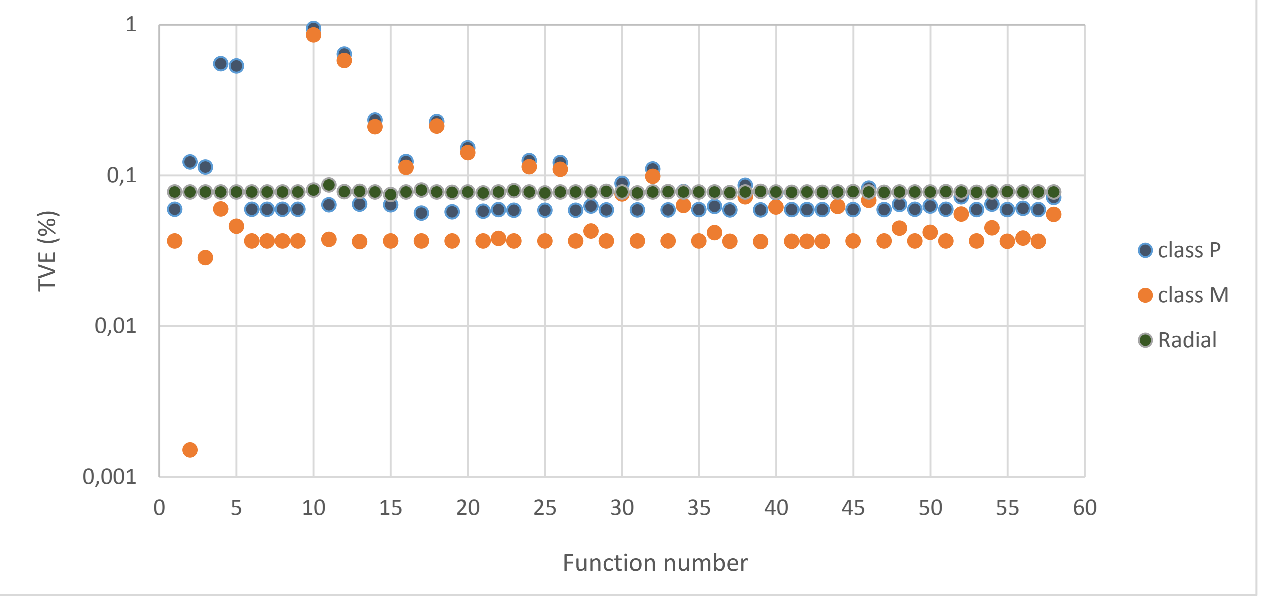
CALCULATION RESULTS



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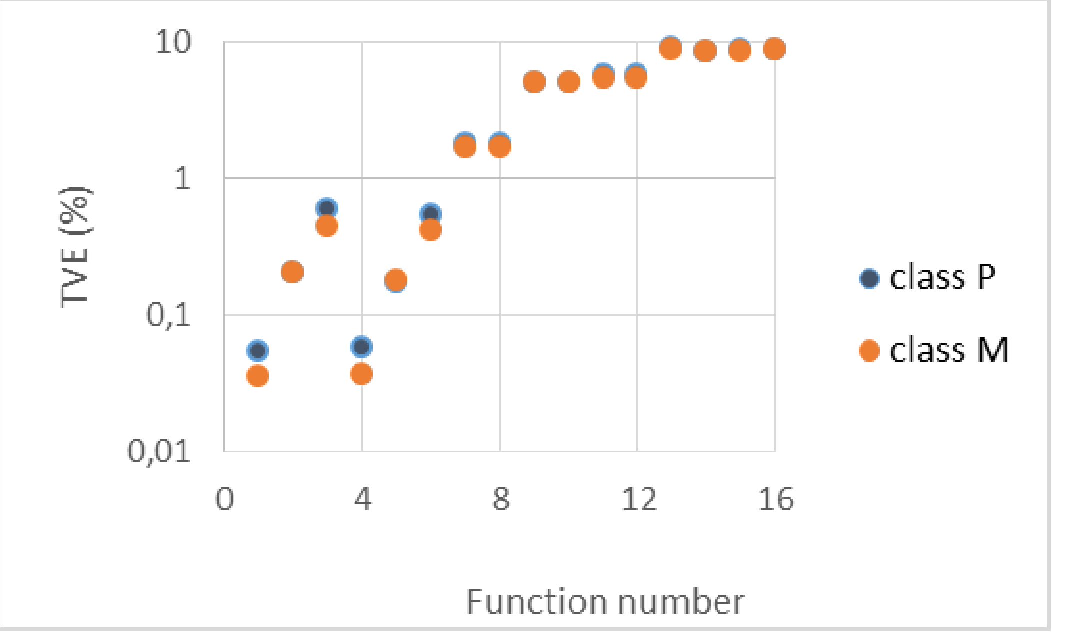
CALCULATION RESULTS

Calculations for all dynamic functions described in Standards, i.e.:

- a signal with sinusoidal magnitude modulation with modulation magnitude equal 0,1 pu and varied modulation frequency: 0,1 Hz, 2 Hz, 5 Hz (functions 1-3),
- a signal with sinusoidal phase modulation with modulation angle equal 0,1 radian and varied modulation frequency: 0,1 Hz, 2 Hz, 5 Hz (functions 4 - 6),
- a signal with positive and negative linear ramp frequency with final frequency equal 48 Hz and 52 Hz (functions 7 - 8),
- a signal with positive and negative step changes in magnitude equal 0,1 pu at two instants of time (functions 9 - 12),
- a signal with positive and negative step changes in phase equal 0,1 radian at two instants of time (functions 13 – 16).

CALCULATION RESULTS



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CALCULATION RESULTS

Parameter	Admissible values	Function number							
		Changes in magnitude				Changes in phase			
		9	10	11	12	13	14	15	16
Class P quadrature filters									
Delay time (s)	0,0167	0,0002	0,0002	0,0017	0,0016	0,0000	0,0002	0,0000	0,0002
Response time (s)	0,0400	0,0222	0,0240	0,0220	0,0227	0,0264	0,0263	0,02592	0,0260
Overshoot/ undershoot in %	5	0	0	0	0	0	0	0	0
Class M quadrature filters									
Delay time (s)	0,0167	0,0002	0,0002	0,0017	0,0002	0,0002	0,0008	0,0000	0,0002
Response time (s)	0,4670	0,0298	0,0308	0,0299	0,0299	0,0747	0,0777	0,0747	0,0777
Overshoot/ undershoot in %	10	0,06	0,06	0,06	0,06	1,11	1,13	1,11	1,12

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CONCLUSIONS

Results obtained for the quadrature filters it can be stated that:

1. For the steady-state functions the maximum TVE value does not exceed 1% (the admissible value given in Standards) in any of the three methods for all steady-state functions;

CONCLUSIONS

2. For the dynamic functions, in terms of the maximum TVE value:

- for the signal with sinusoidal magnitude and angle modulation (functions 1-6), the admissible TVE value given in Standards, i.e. 3%, is not exceeded for any function;
- for the signal with positive and negative linear ramp frequency (functions 7 - 8) the admissible TVE value given in Standards, i.e. 1% is exceeded for both functions;
- for the signal with positive and negative step changes in magnitude and phase (functions 9 - 16) the maximum TVE value is not important as Standards do not define its admissible value. Instead, it is necessary to calculate delay and response time as well as overshoot/undershoot. The results for these values are given in Table 1. Having compared the results of delay time, response time and overshoot/undershoot with the admissible values given in Standards, it can be stated that admissible values are not exceeded for any function in this group.

CONCLUSIONS

Comparing the results it can be stated that the TVE value for all steady-state functions and in any of the three methods does not exceed 1% (the admissible value given in Standards).

The best results are obtained by means of the radial neural network as for all steady-state functions the TVE value is smaller than 0,1%.

While comparing the results obtained by means of two types of quadrature filters with those from the radial artificial neural network, it was noticed that the quadrature filters results are visibly worse for the functions where a signal frequency change occurs (steady-state functions 2 – 5 and dynamic functions 7 - 8).

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