# Advantages of the Walsh Functions in the Measurement of Reactive Power in the Electric Power Systems

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*Abstract*—**In this paper a reactive power (RP) measurement method is proposed. Application of Walsh function (WF) based algorithms allowed to simplify the multiplication operations required for the evaluation the RP in the single-phase and three-phase power systems. One of the unique advantage of the used method is toe eliminate the phase shift operation between the voltage and current signals that is required foe measurement of RP. Limitations and proposals for future performance enhancements of the analyzed algorithms are also discussed. The simulations performed by use of Matlab 6.5 environment have confirmed the validity of the algorithms for measuring of RP in power systems. The simulation results have demonstrated the advantages of Walsh functions in that the computational demands is substantially reduced.**

*Index Terms*— **measurement, reactive power, unbalanced three-phase systems, instantaneous power signal, Walsh function.**

## I. Introduction

THE reactive power (RP) is an integral part of the total electric power in power systems. In spite of the negative effect of the reactive power on the normal operating of the power systems, reactive power is the inherent phenomena of the most of power system components, such as electric machinery, energy transmission and distribution systems, power transformers, etc. All these power systems components have the behavior to store an electromagnetic energy, because they include the reactive components, mainly, inductance in the wide range power systems applications. That's just the main cause for the existence of the reactive power in power systems.

The higher the reactive power the larger the current required for transmission the same amount of energy from source to the user. This problem significantly reduces efficiency of the energy transmission in transmission and distribution lines. Different type of compensation circuits have been developed and applied for the increasing an efficiency of the energy transmission process through compensation of reactive power. The level of reactance to be imposed by the compensation system depends on the value of the reactive power in existing power system, that is why, proper measurement of reactive power in power systems is the one of the extremely important scientific research problems.

In the field of measurement of reactive power the various methods and the algorithms have been developed and published in the scientific journals and international conference proceedings during last decade. The most of the known methods for measuring reactive power are based on the digital measuring approaches, although analog measurement methods are the most suitable for the application where the low-cost and simplicity are of the prime importance. Among the existing methods the reactive power measurement methods using different type of transforms such as Fourier, FFT, DFT, Wavelet, Walsh, etc form class of measurement methods designed for application as the imbedded part of complex power measurement and analysis systems.

Fourier and Wavelet transforms based measurement methods require generation set of orthogonal waveforms (discrete or analog). Since these transforms require multiplication and summation of the signals in the complex domain, the applications of Fourier as well as the Wavelet transform approaches are accompanied with the increase of the volume of required operations resulting to the high cost and less speed.

In this aspect use of Walsh functions for reactive power measurement reduces the volume of operations required for multiplication of the input signal by the Walsh function. Since Walsh functions have only two values, +1 and -1 over the normalized period, it becomes significantly simple to perform multiplication operation. Really, the multiplication of the signal by +1 is equivalent to the original signal. In other words, signal remains unchanged.

Multiplication of the given signal by -1, actually, is the same operation as the inverting of the original signal. This is main advantage of the Walsh transform based method of reactive power measurement. By use of this approach the series of instruments have been developed, investigated, and simulated for single- as well as the three-phase power system networks.

Among the existing RP measurement methods the methods using the shifting of the one of the power components, voltage or current, by the $\pi/4$ , and then multiplication these components, are widely used in applications where the requirements to the power network harmonic distortions are not critical. One way to eliminate an effect of input frequency

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change on the output result is the use of frequency insensitive digital sampler for shifting the input voltage signal by $\pi/4$.

The design and implementation of RP sensors and measurement instruments is currently dictated by the strong demands to the electrical energy savings during transmission and distributions. The evaluation of the RP is also one of the important tasks in electric power industry, especially in the electrical energy quality estimation and control. The RP influences directly to the power factor and as a result overloads the connecting cables between the electrical energy sources and energy user and plays a vital role in the stable operation of power systems. Moreover control of RP and proper selection of the compensating method and corresponding devices mostly depend on the knowledge about the portion of reactive component in the total power.

The classic way to determine the reactive power includes evaluation of the reactive power by using the measured values of the apparent power *S,* and the active power *P.*

This way of RP evaluation requires the measurement of the root mean square (RMS) values of voltage U and current I, and then performing the multiplication operation in order to obtain apparent power S. But this operation is complicated due to the measuring of the RMS values of U and I, which are difficult to measure.

The extension of the wavelet transform to the measurement of RP component through the use of a broad-band quadrature phase-shift networks is demonstrated in [1]. This wavelet-based power metering system requires the phase shift of the input voltage signal. In [2] the application of new frequency insensitive quadrature phase shifting method for reactive power measurements has been verified by using a time-division multiplier type wattmeter. An electronic shifter based on stochastic signal processing for simple and cost-effective digital implementation of a reactive power and energy meter was developed in [3]. The development of a method using artificial neural networks to evaluate the instantaneous reactive power is described in [4]. In this method the back-propagation neural network is used to approximate the reactive power evaluation function. In [5] the digital infinite impulse response filters are used to measure the reactive power.

Although proposed algorithm allows to evaluate the harmonic components of the RP, the suggested method is still complex because the performing of the filtering procedures.

Most of known research works are based on using the method of averaging the value of the product of the current samples and the voltage samples with shifting to the quarter one of the samples (current or voltage) relatively to another.

Although the Fourier transform (FT) based digital or analogue filtering algorithms allow the evaluation of RP without shifting operation but a large number of multiplication and addition operations are required when applying FT algorithms for RP evaluation. For example for a 16 point DFT $16^2 = 256$ complex multiplications and $16 \times 15 = 240$ complex addition operations are required. The various algorithms (for example FFT known as the Cooley Tukay algorithm) have been developed to reduce the number of multiplication and addition operations by use of the computational redundancy inherent in the DFT. Unfortunately, FT based algorithms are still computationally complex.

The attraction of WF based approach to RP evaluation comes from the key advantages such as following:

(a) a requirement of IEEE/IEC definition of a phase shift of $\pi/2$ between the voltage and the current signals, typical for reactive power evaluation is eliminated from signal processing operation;

(b) the multiplication operation between tow digital data is replaced with the multiplication operation between digital data and positive or negative unit(+1 or -1). In other words, the multiplication operation is performed by simple altering the sign of the given digital data from positive to the negative sign so that to be multiplied by -1. Thus the WT analyzes signals into rectangular waveforms rather than sinusoidal ones and is computed more rapidly than, for example FFT. WT based algorithm contains additions and subtractions only and as a result considerably simplifies the hardware implementation of RP evaluation.

The authors in [6] have analyzed WT algorithms employed to energy measurement process and they have shown that the Walsh method represents its intrinsic high-level accuracy due to coefficient characteristics in energy staircase representation. Authors in [7] states that decimation algorithm based on fast WT(FWT) has better performance due to the elimination of multiplication operation and low or comparable hardware complexity because of the FWT transform kernel.

The basic idea of this WF based algorithm consists in the resolving of the voltage and current signals separately along the WFs, at first, and then obtaining the RP as the difference of the products of the quadrature components. At least four multiplication-integration, two multiplication, and one summation operations required for RP evaluation makes this algorithm comparatively complex and less convenient for implementation. It was the aim of this paper to evaluate RP component from instantaneous power signal without phase shift of $\pi/2$ between the voltage and the current waveforms with relatively less computational demands. This objective was achieved by using the WF.

The paper is organized as follows. In section two the WF based analogue and digital signal processing approaches for RP evaluation are described. The DSP based evaluation approach by using discrete is proposed in section three. In section four the simulation results of WF based RP evaluation system are given. Section five includes the conclusion of the paper.

## II. A CONTINUES TIME AND DESCRETE TIME RP EVALUATION ALGORITHMS

### *A. Continues Time Measurement Algorithm*

When in single-phase circuit a source voltage *u(t)* and a current flowing through load *i(t)* are the pure sinusoidal signals, the instant power $p(t)$ is given by [8]

$$p(t) = P - [P\cos 2\omega t + Q\sin 2\omega t], \tag{1}$$

where $P$ is the average or active power in Watts, $Q$ the reactive power in VARs, $\omega = 2\pi/T$ the power system frequency in $rad/\sec$, $T = 1/f$ the period in $\sec$, and $f = 50Hz$ is liner frequency in Hz.

Time diagram representation of the right-hand side terms of (1) is shown in the Fig.1. Fig.2 represents the third order WF, $Wal(3,t)$ with the normalized period of $T/2$ [9].

Multiplication of both sides of (1) by the third order WF, $Wal(3,t)$ is given by

$$p(t)Wal(3,t) = PWal(3,t) - P\cos 2\omega t Wal(3,t) - Q\sin 2\omega t Wal(3,t) \quad (2)$$

Time diagram representation of the right-hand side terms of (2) is shown in the Fig.3. Note that multiplication of (1) by the $Wal(3,t)$ results in rectification of reactive component of the power, $p(t)$ (Fig.3, curve 1).

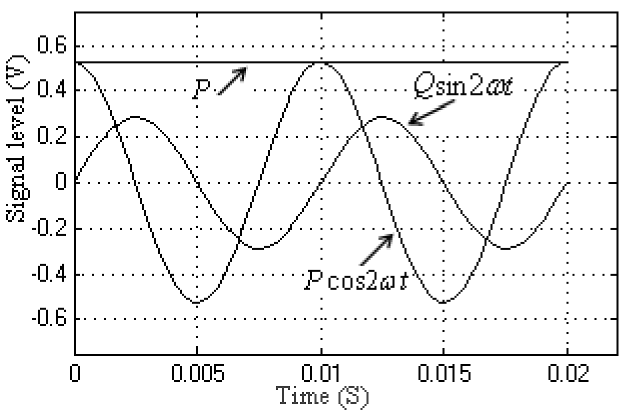


Fig. 1. Graphical interpretation of the power components defined by (1): $u(t) = 2.4\sin\omega t$ $i(t) = 0.5\sin(\omega t - 0.5)$, $f = 50Hz$

As the next step we take integral from both sides of (2) during time period of $T$:

$$\frac{1}{T}\int_0^T p(t)\cdot Wal(3,t)dt = \frac{1}{T}\int_0^T PWal(3,t)dt - \frac{1}{T}\int_0^T P\cos 2\omega t\cdot Wal(3,t)dt$$
$$-\frac{1}{T}\int_0^T Q\sin 2\omega t\cdot Wal(3,t)dt \quad (3)$$

As can be seen from Fig.3 the average value of both product functions of $PWal(3,t)$ and of $PCos2\omega t\cdot Wal(3,t)$ during the time period T equal to zero. Thus, the first and second integrals in the right-hand side of (3) become zero. Thereby (3) is rewritten as follows

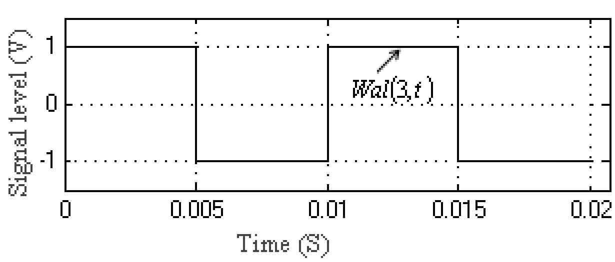


Fig.2. Graphical interpretation of third order Walsh function.

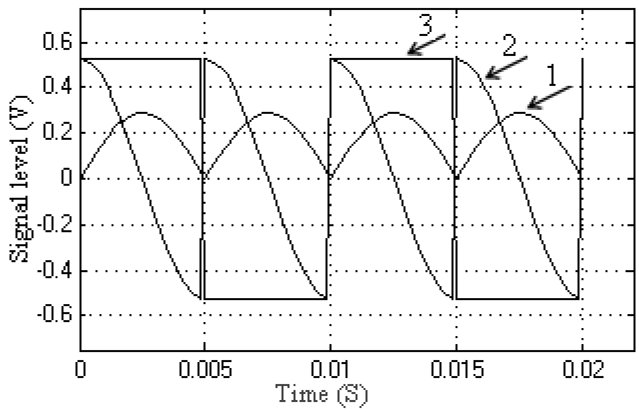


Fig.3. Graphical interpretation of third order Walsh function
1- $Q\sin 2\omega t\cdot Wal(3,t)$ ; 2- $P\cos 2\omega t\cdot Wal(3,t)$ ; 3- $PWal(3,t)$

$$\frac{1}{T}\int_0^T p(t)\cdot Wal(3,t)dt = \frac{1}{T}\int_0^T Q\sin 2\omega t\cdot Wal(3,t)dt \quad (4)$$

Carefully look at the curve 1(Fig.3) and the integral given by (4) allow us to summarize that the average value of the oscillating reactive power can be measured by use of the derived algorithm without the phase-shift operation of the voltage(or current) signal to the $\pi/2$ with respect to the current(or voltage)signal.

Mathematical expression for RP evaluation is obtained from (4) considering Fig.3 (curve 1), as follows

$$Q = \frac{1}{T}\int_0^T p(t)\cdot Wal(3,t)dt = \frac{1}{T}\int_0^T \left|Q\sin(2\omega t)\right|dt \quad (5)$$

Thus we obtained an equation (5) that allows measuring of the average value of the reactive power.

*B. Discrete time Measurement Algorithm*

To derive the digital measurement algorithm for RP an expression for instantaneous power given by (1) can be rewritten in discrete form as follows

$$p(n) = P - \left[P\cos\left(\frac{4\pi}{N}\cdot n\right) + Q\sin\left(\frac{4\pi}{N}\cdot n\right)\right] \quad (6)$$

Where $n = 0,1,2,..., N-1$. $N$ is the number of samples in power of 2. N is determined in accordance with Nyquist criterion, $N = T/T_s$, $T_s$ is the sampling period.

For derivation of the digital algorithm for the RP evaluation we use the discrete expression of the WF [10]-[13]:

$$Wal(i,\beta_k) = (-1)^{\sum_{k=1}^{m}(\omega_{m-k+1}\oplus\omega_{m-k})\beta_k} \quad (7)$$

where $i$ is order of WF in the WF system, $i$=0,1,2,…,N-1, $\beta_k$ is argument of WF and defines the bit(digit) coefficients of $\beta_k$ represented in binary code, $\beta = (\beta_1, \beta_2 ... \beta_k)_2$, $\beta_k = 0{,}1$, $\omega_m$ is the bit(digit) coefficients of $\omega_m$ represented in binary code, $\omega = (\omega_0, \omega_1, \omega_2 ... \omega_m)_2$, $\omega_m = 0{,}1$, $m$ is a binary representation of highest-order WF serial number in the WF system. For evaluation of the reactive component of EP we use the third-order WF, $Wal(3,\beta_k)$. For the third-order Walsh function $\omega = 3$ therefore only $\omega_6 = 1$ and $\omega_5 = 1$. Remaining bit coefficients of the $\omega_m$, $m = 1,2,3,4$ are equal to the zero: $3 = (000001)_2$. In this case the third-order WF is given by

$$W(3,\beta_2) = (-1)^{(\omega_5 \oplus \omega_4)\beta_2} = (-1)^{(1\oplus 0)\beta_2} = (-1)^{\beta_2} \tag{8}$$

The argument, $\beta_k$ changes depending on normalized time of T=0.02sec. as shown in the Fig.4. Fig.5 depicts the $\beta_2$ and third-order discrete WF.

To achieve the stated in the introduction objective we multiply both sides of (6) by (8) and sum the product terms over the $n = 0,1,2,..., N-1.$, that is

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = \frac{1}{N}\sum_{n=0}^{N-1} P(-1)^{\beta_2} - \frac{1}{N}\sum_{n=0}^{N-1} P\cos(4\pi n/N)(-1)^{\beta_2}$$
$$-\frac{1}{N}\sum_{n=0}^{N-1} Q\sin(4\pi n/N)(-)^{\beta_2} \tag{9}$$

Since the $(-1)^{\beta_2}$ is periodic and $\cos(4\pi n/N)$ is orthogonal with the $(-1)^{\beta_2}$ over the $n = 0,1,2,..., N-1$, the first and second terms on the right side of (9) vanish. Thereby, the (9) is rewritten as

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = -\sum_{n=0}^{N-1} Q\sin(4\pi n/N)(-)^{\beta_2} \tag{10}$$

As can be seen from Fig5, third order discrete WF with the normalized period of $T$ has the discrete values defined as:

$$(-1)^{\beta_2} = \begin{cases} +1, \text{at the intervals of } [0,N/4) \text{and} [N/2,3N/4] \\ -1, \text{at the intervals of } [N/4,N/2) \text{and} [3N/4,N-1] \end{cases}$$

So Eq (10) can be written as

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = \frac{1}{N}\left[\sum_{n=0}^{N/4-1} Q\sin\left(\frac{4\pi}{N}n\right)\right. \tag{11}$$
$$\left. - \sum_{n=N/4}^{N/2-1} Q\sin\left(\frac{4\pi}{N}n\right) + \sum_{N/2}^{3N/4-1} Q\sin\left(\frac{4\pi}{N}n\right) - \sum_{n=3N/4}^{N-1} Q\sin\left(\frac{4\pi}{N}n\right)\right]$$

The analysis indicated in Fig.3 and 5 intervals shows that the function of $\sin(4\pi n/N)$ has negative values at the intervals of *[N/4, N/2-1]* and *[3N/4, N-1]*, then the Eq. (11) simplifies to

$$\frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} = \frac{1}{N}\sum_{n=0}^{N-1} \left| Q\sin\left(\frac{4\pi}{N}n\right)\right| \tag{12}$$

Since

$$\frac{1}{N}\sum_{n=0}^{N-1} \left| Q\sin\left(\frac{4\pi}{N}n\right)\right| = Q,$$

Eq (12) defines the RP over the period of $T$

$$Q = \frac{1}{N}\sum_{n=0}^{N-1} p(n)(-1)^{\beta_2} \tag{13}$$

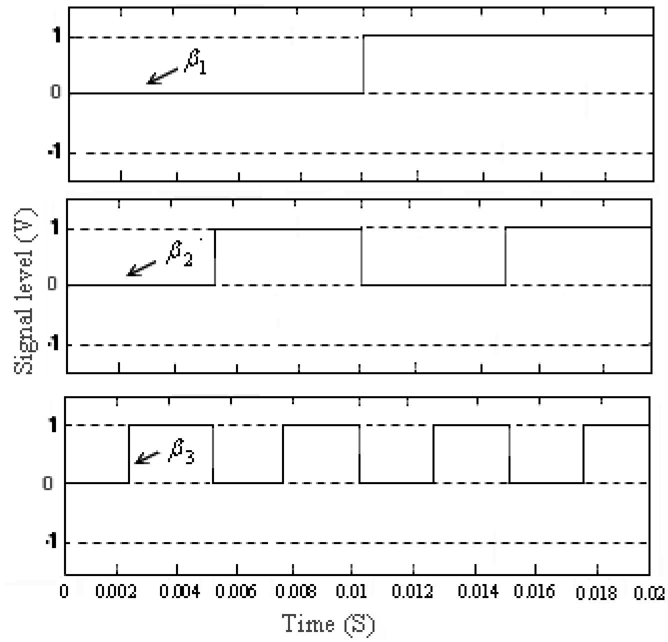

Fig.4. Time representation of final three bit coefficients of the binary representation of $\beta_k$

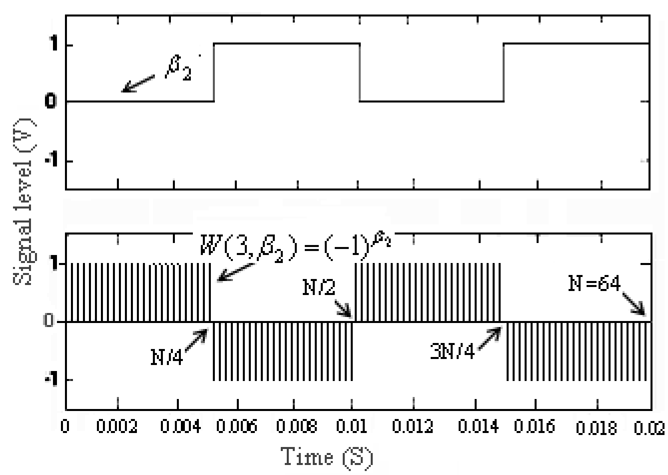

Fig.5. Time representation of $\beta_2$ and third-order discrete WF

## III. DESIGN OF ELECTRONIC REACTIVE POWER METER

The block diagram of electronic RP meter is shown in the Fig.6. The voltage and current signals are fed to the inputs of the analog multiplier (AD633), which produces time continuous output waveform which is proportional to the product of the input voltage and current signals, i.e. instantaneous power $p(t)$ defined by (1). Output waveform of AD633 is diagramed in the Fig.7a. The output of AD633 is fed to the analog-to- digital converter (ADC0804) controlled by the control logic (CL). The ADC0804 converts the input signal $p(t)$ to the output digital data samples $p(n)$ from each output signal of the digital sampler (DS). The digital samples $p(n)$ defined by (6) are shown in the Fig.7a. The sampled signals are formed from input voltage signal $u(t)$ to achieve the frequency insensitive measurement. The output signals of the DS are shown in the Fig.7b. The output from the ADC0804 is fed to the inputs of the up-down counter (UDC) through the multiplexer. The multiplexer is used to connect the output of the ADC0804 to either the up input or the down input of the UDC in accordance with the (11). First and third quarter part of the $p(n)$,

$i = 1,2,3,4,5,6,7,8,17,18,19,20,21,22,23,24$ (See Fig.8a) are entered to the up input and the second and the forth quarter parts of the $p(n)$,

$i = 9,10,11,12,13,14,15,16,25,26,27,28,29,30,31,32$ (Fig.8b) are entered to the down input of the UDC. So in accordance with (11) the remainder number in the UDC to the end of the second period of the input signal becomes equal to the RP of the investigated circuit. The UDC binary output is indicated in the display.

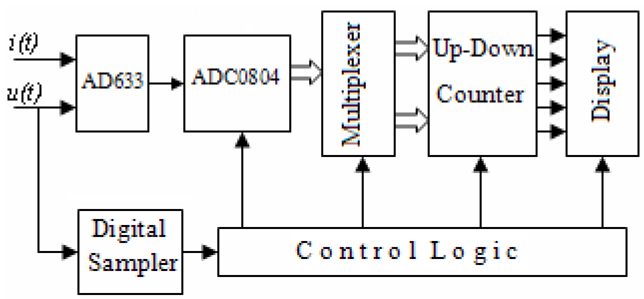


Fig.6. Block diagram of electronic powermeter

## IV. DIGITAL SAMPLER

The important component of the proposed electronic RP meter providing the independence of the measurement results from the change of input signal frequency is the DS. DS produces sampling signals with the predetermined frequency. Moreover, sampling frequency is correlated with the frequency of the input signal to be measured.

The block diagram of the DS is represented in the Fig.9. A zero crossing detector produces the pulses when input voltage signal $u(t)$ crosses the zero level. As seen from Fig.7, the duration of this impulses becomes the half (T/2) of the full period $T$ of the input voltage signal $u(t)$. During this first period of $T$ the CL enables the output impulses of the clock to be passed through the binary ripple counter (BRC) only to the input of the binary storage counter1.

The counter capacity of the BRC is defined in accordance with the demand to the sampling rate of the instantaneous power signal $p(t)$.

The number of impulses stored in the binary storage counter1 to the end of time interval of $T$ is given by,

$$M = (f_c T)/N \tag{14}$$

Where, $f_s$ is the clock frequency and $N$ is the counter capacity of the BRC ( $N = 2^m$, $m$ is the number of bits).

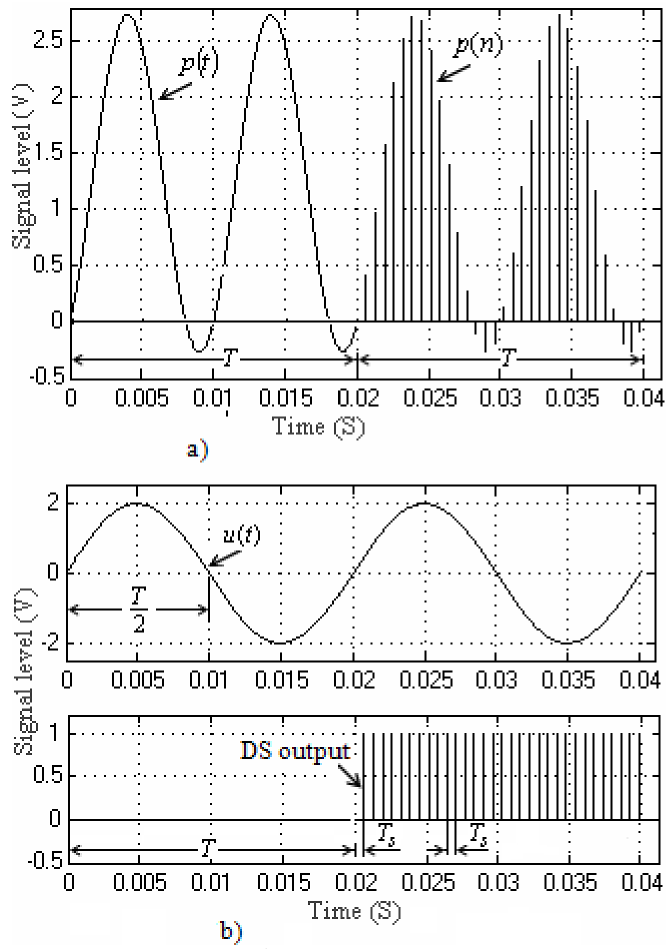


Fig.7. Output waveforms: a) analog multiplier and ADC; b) input $u(t)$ and DS output signals.

Note that, $N$ is defined from Shannon criterion on sampling frequency At the beginning of the second period $T$ of $u(t)$ the CL enables the output impulses of the clock to be passed only to the input of the second binary storage counter2. When the number of the clock impulses stored in the second binary storage counter becomes equal to the $M$, i.e. the number, stored in the first BSC1 the code comparator (CC) produces its first output impulse. This impulse resets the BSC2 to zero and becomes the first output impulse of the DS (Fig.7). Since the clock pulses continue to enter to the input of BSC2 continuously during second full period of $T$ (Fig.7). When the number of impulses counted by the BSC2 becomes again equal to the $M$, the CC produces the second output impulse of the DS resetting the BSC2 to zero.

The time interval between the instant of BSC2 was reset to zero and the time instant of BSC2 has counted $M$ number of impulses is given by

$$T_s = f_c / M \tag{15}$$

Where $T_s$ is the sampling interval (See Fig.7) and $f_s = 1/T_s$ is the sampling frequency. Substitution (15) into (16) gives the expression relating sampling interval $T_s$ to the input signal period $T$:

$$T_s = T / k \tag{16}$$

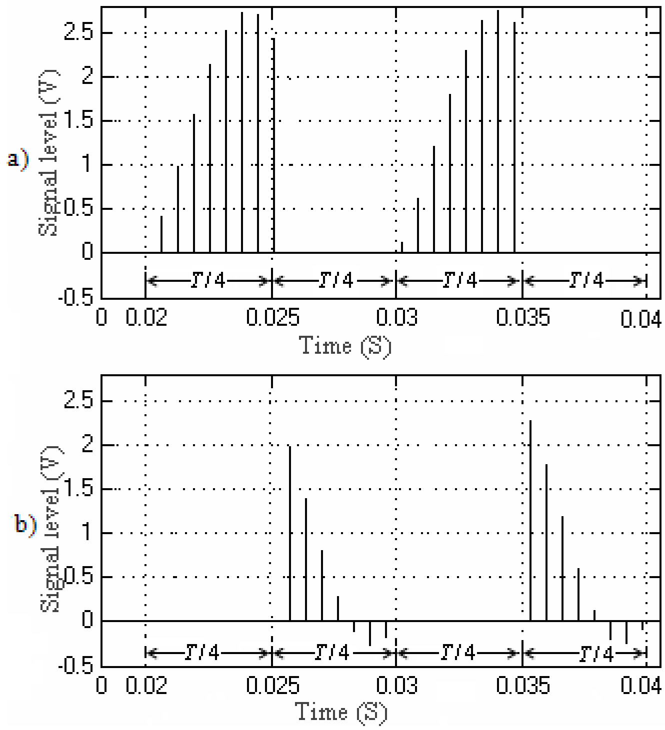


Fig.8. Sampled power signal $p(n)$ : a) first and third quarter part; b) second and forth quarter part.

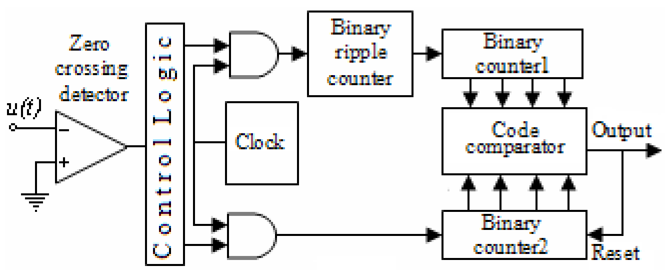


Fig.9. Digital sampler

So repetition interval of the DS output impulses is the $k$ times less the $T$ . This relationship can also be written in terms of the DS input and output frequencies:

$$f_s = kf \tag{17}$$

It is evident from (15) and (19) that, the number of collected data N do not depend on the input signal frequency; consequently measurement results are also independent on the input signal frequency.

Carefully look at derived expressions of (15) and (16) allows to state that designed electronic meter meets the requirement of coherent data acquisition and thereby is the good solution for the preventing of the energy leaking from spectral components [6] when input signal frequency $f$ is to vary because of the power distribution system instability. Thus, sampling period $T_s$ becomes the function of the being sampled input signal period $T$ . Proposed approach to DS implementation provides coherent data acquisition as a result avoids the spectral leakage in the comparatively wide range deviations of the power frequency in the investigated circuit. Thus an extreme requirement on different algorithmic and hardware solutions to achieve the coherent sampling while dealing with the sampled data is avoided.

## V. Simulation Results

The simulation circuit of the proposed novel analog signal processing (ASP) structure for evaluation of RP and active power from instantaneous power $p(t)$ is shown in Fig.10. The simulation circuit includes: voltage source, $u(t)$ ; current source, $i(t)$ ; multiplier, which produces, the instantaneous power $p(t) = u(t)i(t)$ ; zero- and third-order Walsh code generators; the pair of multipliers for obtaining the products of the zero-and third-order WFs by $p(t)$; integrating analog-to-digital converters ADC1 and ADC2 used to produce digital codes proportional to the evaluated values of the active and the reactive components of the EP, respectively. During experimental studying the input voltage, $u(t)$ and the current, $i(t)$ signals were taken as [14-16].

$$u(t) = U_m \sin(\omega t) \text{ and } i(t) = I_m \sin(\omega t - \varphi) ,$$

where $I_m$ =2A, $U_m$ =4V, $\omega = 2\pi f$ , $f$ = 50 is the linear frequency in Hz, $\omega$ =314 is frequency in rad/sec, $\varphi$ -phase shift between the voltage $u(t)$ and the current $i(t)$ signals. The phase shift, $\varphi$ between the voltage $u(t)$ and the current $i(t)$ signals has been varied in the interval of $\varphi = 0 - 90°$ . The signal proportional to the instant value of the power $p(t)$ which is applied to the first inputs of the pair of multipliers is given by,

$$p(t) = 8\sin(314t) * \sin(314t - \varphi)$$

The time representation of the signals $p(t)$ and $p(t) * Wal(3, \beta_k)$ are shown in the Fig.11. The signals $p(t)$ and $p(t) * Wal(3, \beta_k)$ are integrated and converted to

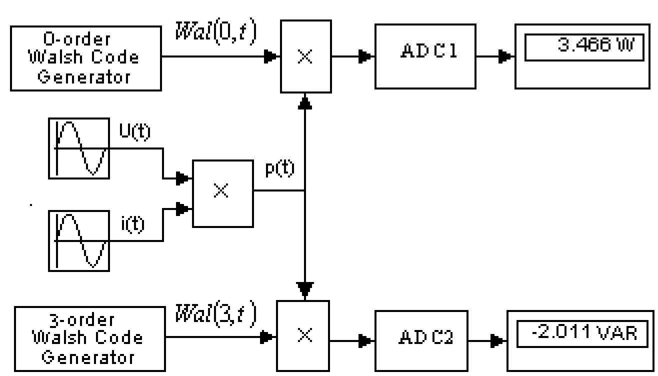


Fig.10. Proposed ASP technique based structure for the active and reactive power evaluation

digital form using the ADC1 and ADC2, respectively. The digital codes, generated by ADC1 and ADC2 represent resulting evaluated values of the active and the reactive components of the electrical power (Fig.10). The results of the experimental verification are represented on the Table 1.

From the Fig.12 it can be seen the error appearing because of the change of the phase shift φ in the interval of from 0 to 90°.

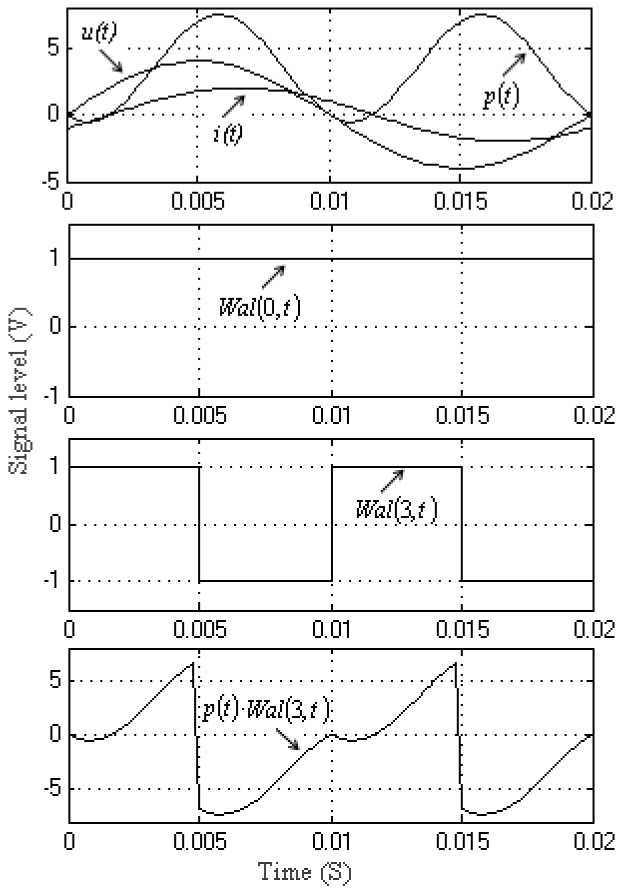


Fig.11. The Components outputs signals versus time representation

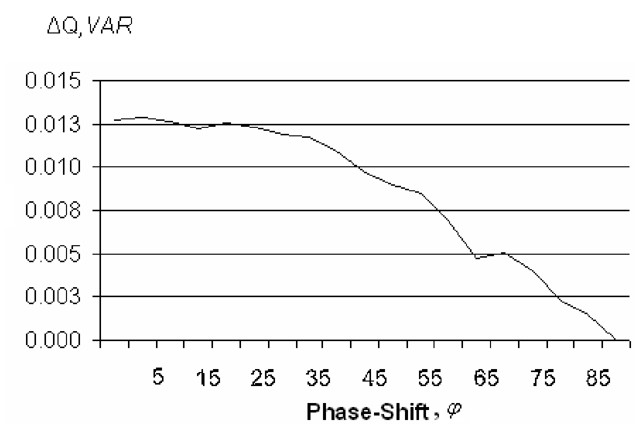


Fig.12. Relation between the measurement error $\Delta Q$ and the phase-shift rate $\varphi$ .

The essential advantage of the proposed method for evaluation of RP has been verified by experimental studies. One of these advantages is that in contrast to the known existing methods the proposed method does not require a phase shift of the current signal to the $\pi/2$ with respect to the voltage signal. The phase shift operation requires the corresponding hardwire which may result in the additional measurement error. The author is currently working towards the estimation and correction of harmonic distortions influence on proposed RP evaluation method.

TABLE I
SIMULATION RESULTS OF THE RP EVALUATION ALGORITHM

| | | Results of calculating | | Outputs of the simulation circuit | | Percentage error |
|---|---|---|---|---|---|---|
| | $\varphi$ | P,W | Q,VAR | P,W | Q,VAR | δ |
| 0 | 0 | 4,000 | 0,000 | 4,002 | -0,0127 | 100 |
| 1 | 5 | 3,985 | -0,348 | 3,987 | -0,3613 | 3,558 |
| 2 | 10 | 3,939 | -0,694 | 3,941 | -0,7069 | 1,790 |
| 3 | 15 | 3,864 | -1,035 | 3,866 | -1,047 | 1,169 |
| 4 | 20 | 3,759 | -1,367 | 3,761 | -1,38 | 0,912 |
| 5 | 25 | 3,626 | -1,690 | 3,627 | -1,702 | 0,724 |
| 6 | 30 | 3,465 | -1,999 | 3,466 | -2,011 | 0,593 |
| 7 | 35 | 3,277 | -2,293 | 3,278 | -2,305 | 0,508 |
| 8 | 40 | 3,065 | -2,570 | 3,066 | -2,581 | 0,424 |
| 9 | 45 | 2,830 | -2,827 | 2,83 | -2,837 | 0,342 |
| 10 | 50 | 2,573 | -3,063 | 2,572 | -3,072 | 0,292 |
| 11 | 55 | 2,296 | -3,275 | 2,296 | -3,284 | 0,259 |
| 12 | 60 | 2,002 | -3,463 | 2,002 | -3,47 | 0,201 |
| 13 | 65 | 1,693 | -3,624 | 1,693 | -3,629 | 0,131 |
| 14 | 70 | 1,370 | -3,758 | 1,368 | -3,763 | 0,135 |
| 15 | 75 | 1,038 | -3,863 | 1,036 | -3,867 | 0,103 |
| 16 | 80 | 0,697 | -3,939 | 0,696 | -3,941 | 0,057 |
| 17 | 85 | 0,352 | -3,985 | 0,3469 | -3,986 | 0,037 |
| 18 | 90 | 0,003 | -4,000 | 0,0008 | -4,0000 | 0,000 |

## VI. CONCLUSION

The evaluation of reactive component of EP with application of a WF simplifies the volume of computing operations on some order in comparison with sets of algorithms based on decomposition of signals on harmonics (trigonometric components). Evaluation of RP using WF results in certain advantages:

a) During the processing of the signals on the base of WF time-shifting of the signals acts on the structure of the signals. This influence becomes useful during the evaluation of the power components allowing the obtaining extra knowledge concerning the phase-shifts on the harmonics of the input signals;

b) The requirement of IEEE/IEC definition of a phase shift of $\pi/2$ between the voltage and the current signals, typical for reactive power evaluation, is eliminated from signal processing operation;

c) The RP is evaluated without the phase-shift operation between the voltage and current waveforms to achieve increased efficiency of computational operations and hardware implementation;

d) During DSP the multiplication of the sample values of the signals by corresponding order WF is performed simply, by alteration of sign of the signal samples from +1 to -1 only during even quarters of the input signal periods.


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## REFERENCES


[1] Branislav Djokic, Eddy So, and Petar Bosnjakovic. "A High Performance Frequency Insensitive Quadrature Phase Shifter and Its Application in Reactive Power Measurements", *IEEE Trans. Instrum. Meas*.,Vol. 49, February 2000, pp.161-165.

[2] W.-K. Yoon and M.J. Devaney. "Reactive Power Measurement Usinq the Wavelet Transform", *IEEE Trans. Instrum. Meas*.,Vol. 49, April 2000, pp.246-252.

[3] S.L.Toral, J.M.Quero and L.G.Franquelo. "Reactive power and energy measurement in the frequency domain using random pulse arithmetic", *IEE Proc.-Sci. Technol*., Vol. 148, No. 2, March 2001, pp.63-67.

[4] T.W.S.Chow and Y.F.Yam. "Measurement and evaluation of instantaneous reactive power using neural networks", *IEEE Transactions on Power Delivery*, Vol. 9, No. 3, July 1994, pp.1253-1260.

[5] A. Ozdemir and A. Ferikoglu. " Low cost mixed-signal microcontroller based power measurement technique", *IEE Proc.-Sci. Meas. Technol*., Vol. 151, No. 4, July 2004, pp.253-258.

[6] A. Brandolini, A. Gandelli, F. Veroni, "Energy meter testing based on Walsh transform algorithms", *Instrumentation and Measurement Technology Conference*, 1994. Conference roceedings, Vol.3, 10-12 May 1994, pp.1317-1320,

[7] Bai liyun, Wen biyang, Shen wei, and Wan xianrong. "Sample rate conversion using Walsh-transform for radar receiver", *Microwave Conference Proceedings*, 2005. APMC 2005. Asia-Pacific Conference Proceedings.Volume 1, 4-7 Dec. 2005.

[8] IEEE Std. 1459-2000, "IEEE Trial Use Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Non-Sinusoidal, Balanced, or Unbalanced Conditions", Institute of Electrical and Electronics Engineers / 01-May-2000 / 52 pages.

[9] Trachtman A.M., Trachtman V.A. *Fundamentals of the discrete signals' theory on the finite intervals*. - M.: Sov. Radio, 1975. -208 p.

[10] A.N. Abiyev, "A new signal processing technique for measurement of the reactive power in the power transmission and distribution systems", Southeastcon 2009, IEEE, Hantsville, AL, USA, pp.356-361.

[11] A.N. Abiyev, "A new electronic reactive power meter based on Walsh Transform algorithms", IEEE Transmission and Distribution Conference and Exposition, 2009 (T&D. IEEE/PES). Chicago, IL, USA, pp. 1-7.

[12] A.N. Abiyev, "A New Signal Processing based Method for Reactive Power Measurements", *Journal Of Computers*, Vol. 4, No. 7, pp.623-630, [doi:10.4304/jcp.4.7.623-630].

[13] P. Carbone and D. Petri, "Average power estimation under nonsinusoidal conditions", *IEEE Trans. Instrum. Meas*., Vol. 49, No 2, Apr. 2000, pp. 333–336.

[14] A.N.Abiyev, I.M. Aliyev, "An Electric Power Measurement Based On Discrete Walsh Transformation", Proceedings of the International Conference *Interactive Systems: The Problems Of Human-Computer Interaction*, 23-27 September 2003, Ulyanovsk, Russia, pp.195-196.

[15] A.N. Abiyev, "The Walsh Function Based Electric Power Measuring Method", Proceedings of the *3rd International Symposium on Electrical, Electronics, and Computer Engineering*, November 23-25, 2006. Nicosia, North Cyprus, pp.177-181.

[16] A.N. Abiyev, "Frequency Insensitive Digital Sampler and Its Application to the Electronic Reactive Power Meter", In: Tarek, S. (Ed.), Advances in Computer and Information Sciences and Engineering. Publisher: Springer Netherlands, Netherlands, 2008, pp. 21-26.


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