FAST PROCESSING OF RECORDED DATA FROM ALTERNATING ELECTRIC PARAMETERS USING THE CALDEQ32 – PROGRAM FOR THE CALCULATION OF DERIVED ELECTRICAL QUANTITIES USING DISCRETE FOURIER TRANSFORM

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Abstract

This paper contains the description of complementing the software CALCULATING OF DERIVED ELECTRICAL QUANTITIES (CALDEQ) and the evaluating algorithms. Authors Š.Žofčík, J.Dopjera, Dr. J. Korec. The working out of these algorithms uses the modification of the knowledge in the publication on the topic:
SYNCHRONIZED SAMPLING PHASOR MEASUREMENTS FOR RELAYING AND CONTROL prepared by working group H-7 of the Relaying Channels Subcommittee of the IEEE Power System Relaying Committee. WORKING GROUPMEMBERS ARE DR. ARUN G. PHADKE, Chairman, B. PICKETT, Vice Chairman [1]. THEORY AND IMPLEMENTATION SYNCHRONIZED PHASOR MEASUREMENTS – Dr. Jaime De La Ree [2].
The evaluating software CALDEQ 32 is an actual version of the software CALCULATING OF DERIVED ELECTRICAL QUANTITIES, that is used for the numeric and vector evaluating of the recorded data (off the real time) form the organized control tests of performance dynamic processes of electrical equipment of all voltage systems.

S. Žofčík has suggested the method of calculating the derived electrical quantities containing the combination of calculating functions of CALDEQ software and the strategy of calculating by the recursive algorithm of the phasor calculation. The actual software package CALDEQ 32 was complemented by this method.
„The combined" method of the calculation of derived electrical quantities from the recorded data, out of the real time of evaluating process, it enables:

- *Analysing the processes containing the components of the higher harmonics*
- *To determine the derivation from the results of the calculations.*

For using the real time it is possible to apply this calculating method in the evaluating and active algorithm of the digital electrical protection

PHYSICAL ANALYSIS OF ELECTRICAL PROCESSES IN ACCORDANCE WITH THE PRINCIPLE OF DECENTRALIZED AND CENTRALIZED EVALUATION IN OPERATION CONDITIONS AS FOLLOWS

Organized or authomated recording and evaluating of values of stationary and nonstationary processes of electrical equipments of all voltage systems. Output of the calculating of derived electrical quantities.

Analysis can be done either on a printer or on a plotter. Output recorded values and graphic vector illustrating of angle-phase analysis.

CALDEQ – CALCULATING OF DERIVED ELECTRICAL QUANTITIES

CALDEQ is a software package, which allows fault analysis in accordance with the principle "decentralized and also centralized" –numeric evaluation – calculations of derived electrical quantities including text, numeric and vector registering.

Results of all calculations in program "CALDEQ" are expressed in the primary electrical quantity values of the heavy duty electrical equipment and systems (calculations contain all constants resulting from transformer ratios, conversion, insulation and adaptation elements).

Calculating of derived electrical quantities as follows:

- Automatic determination of half-periods (or periods) or manual assignation of the evaluation period for derived electrical quantities

- Automatic calibration – the analog channels can be assigned to the same group of channels represented with the same scale, to facilitate the reading of the recording, the scale is determined automatically according to the maximum-recorded amplitude. Thus, for instance, the user can immediately distinguish a single phase fault from a two or three phase fault

- Calculation of the frequency (estimation of subsequent transitions through zero value. Summing of the selected number of half-periods and their average), control of the accuracy of the frequency calculations

- FFT (fast fourier transformation)

- Summing the instantaneous samples of two waveforms, subtraction of the instantaneous samples of two electrical quantity waveforms

- Differences, derivation of electrical quantities waveforms

- Angle analysis and vector representing of three phase of the charts

- Active, reactive, apparent power in different time points and vector representation

- Evaluation of impedance at a given energy system point

- Voltage and current symmetry breaks

- Earth leakage occurrence

- Logic analysis of binary quantities, actual status of process etc. are obtained

- Undesirable distortions of alternating quantities charts
- Losses of ancillary and actuating voltages for automatics and electric protections

THE METHODS OF DERIVED ELECTRICAL QUANTITIES

1. **Calculation Scope Determination and Ways of Searching for Zero Transition**

Searching for Zero Transition

Objectivity reasons require determining exactly both the period or half-period for the purpose of RMS values powers, FFT, impedance … calculations

Zero Transition Searching Modes

- **Automatic**
  The trace is converted on the sample by sample base CALDEQ program and the zero transition point is determined anytime the trace signum is changed (transition from negative to positive values and the order way round) when searching for when searching for periods.

- **Average**

  In case of the so-called noised traces, there is a danger of incorrect determination of periods or half-periods by means of searching zero transition points. Consequently, incorrect results of the subsequent mathematical processing can be obtained. The Average method can be used in such case. Following formula is valid "n"-th sample of the trace:

$$An = \frac{\sum\limits_{i\,=\,n-x}^{n+x} Ai}{2x+1} \quad \text{where x – averaging coefficient}$$

Subsequent zero transition searching steps are the same as for the Automatic method.

Note: Averaging is only used when searching for zero transitions; original measured values are used when making further calculations (RMS value, powers, FFT…).
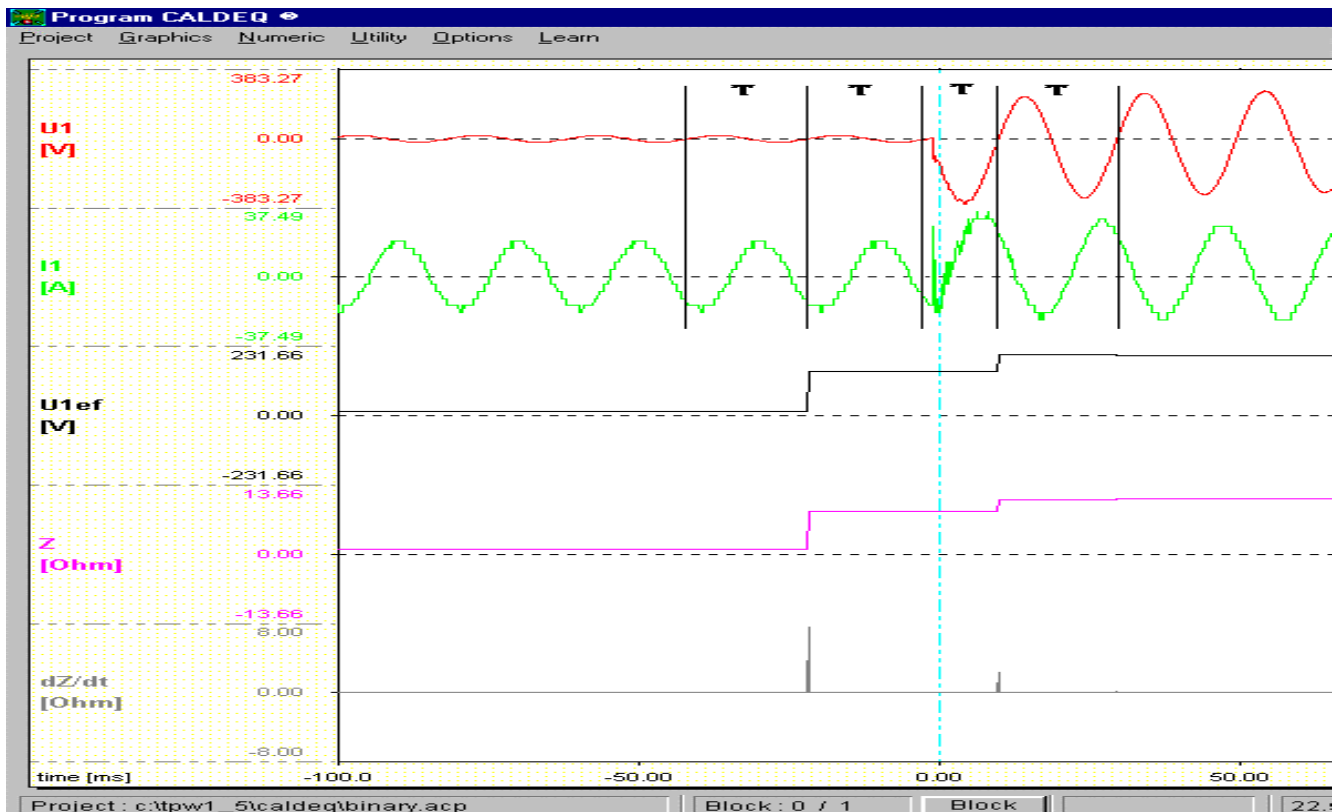

Figure No.1

The beginning of a period can be determined according to the relation:

$P_{start} = n$ if $sign(u_n) - sign(u_{n-1}) = 2$ and $sign(u_n) = 1$

The end of a period can be determined according to the relation:

$P_{finish} = n$ if $sign(u_{n+1}) - sign(u_n) = 2$ and $sign(u_n) = -1$

The time of a period: $T = P_{finish} - P_{start}$

The relations for calculating the basic derived electrical quantities:

- effective value $U_{ef} = \sqrt{1/T \int u^2 \, dt}$

- active power [W] $P = 1/T \int u * i \, dt$

- estimated power [VA] $S = U_{ef} * I_{ef}$

- impedance [Ω] $Z = U_{ef} / I_{ef}$

- frequency [Hz] $f = 1 / T$

The advantages of this method
- This method is dependent neither on the measured sampling frequency or the frequency of the measured and recorded electrical quantity.

The disadvantages of this calculating method

- the calculated derived quantities take into consideration the influence of all higher harmonics components contained in the process of recorded electric quantity

- at automatic searching of the periods or half-periods there can appear a fault, that can be caused by a multiply zero crossing of analysed process. This deviation can be caused by the content of the higher harmonics components in the quantity.
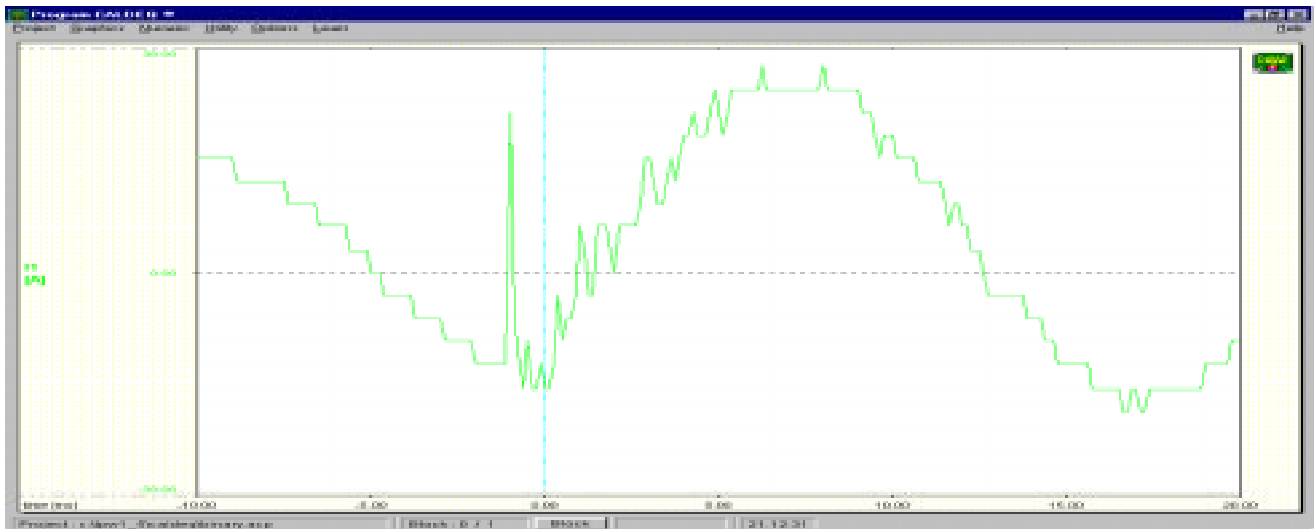

Figure No.2

2. The method of calculating the derived electrical quantities by a recursive algorithm of the phasor calculation
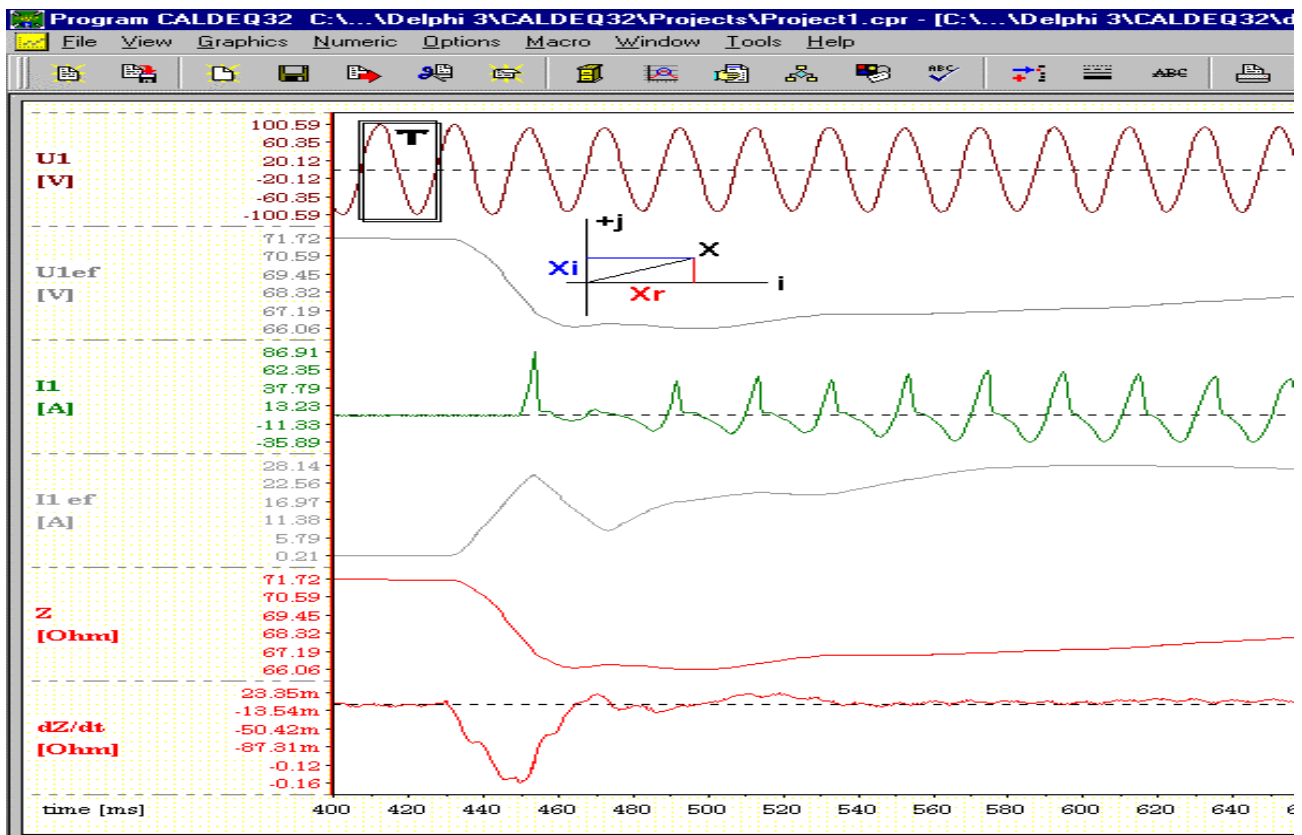

Figure No.3

Real part of phasor $x_r = \Sigma\, x_k * \cos k\theta$ where $k = 1 \div T$ and $\theta = 2*\pi\, /\, T$

Imaginary part of phasor $x_i = \Sigma\, x_k * \sin k\theta$ where $k = 1 \div T$ and $\theta = 2*\pi\, /\, T$

Angle of phasor $\varphi = \arctan(x_i\, /\, x_r)$

The relations for calculating the basic derived quantities:

- effective value $U_{ef} = 1\, /\, \sqrt{2} * \sqrt{(x_r^2 + x_i^2)}$

- active power [W] $P = U_{ef} * I_{ef} * \cos(\varphi_u - \varphi_i)$

- estimated power [VA] $S = U_{ef} * I_{ef}$

- impedance [Ω] $Z = U_{ef}\, /\, I_{ef}$

The advantages of this calculating method

- The calculated electrical quantities that are put into the graph represent a continuous process (see figure No.3).

- It is not necessary to look for the transmissions of electric quantities containing the components of higher harmonics.

- It is possible to find out the tendency of the change of calculated values of derived electric quantities trough a derivation.

The disadvantages of this method
(In the case when in the calculation we use an evaluating window – the time of one period of basic harmonics):

- before introducing the calculation the service must define a nominal frequency of a measured electrical quantity (the time of a period of basic harmonics)

- the condition, in order to safe the precision of the calculation by this method, is a constant frequency of measured quantity through the whole time of measuring and its registration

- the calculation ignores the impact – the content of the components it higher harmonics in analyzed electrical quantity.

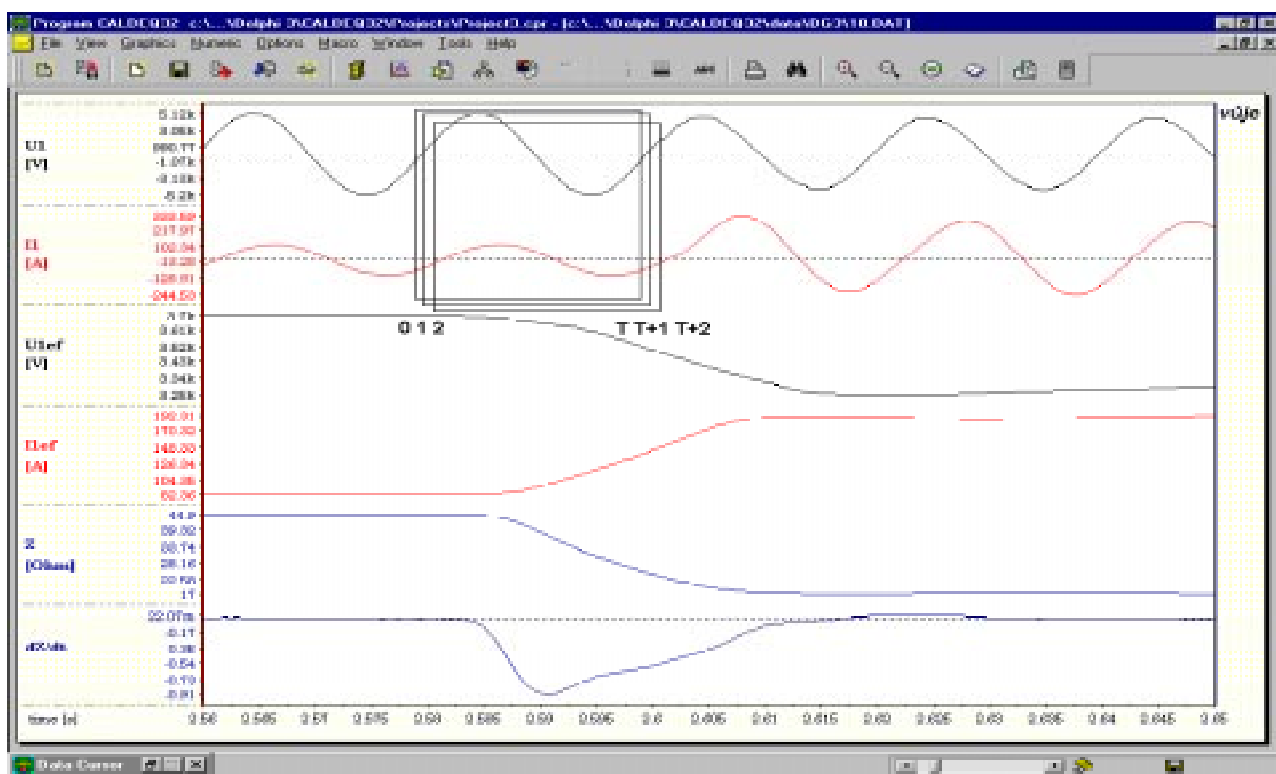## 3. The method of the calculation of derived electrical quantities in a combined way

Figure No.4

This method combines some functions of the both above-mentioned ways of calculating the derived electrical quantities. That means from the first method (CALDEQ software) there are used the relations o calculations and the strategy of the calculation – applying **"THE**

MOVABLE WINDOW" is used from the method of the calculation of derived electrical quantities by a recursive algorithm of the phasor calculation.

The process of calculating the effective value of the electrical derived quantity:

- Choosing the length of the integration interval T. The length of the interval is not so critical as when calculating by a recursive algorithm. The only condition is that the integration interval T has to be bigger or approximately equal to the length of the period of the basic harmonics of the recorded and evaluated process of the electrical quantity.

- In the first step there is calculated and effective value $U_{ef(0 \div T)} = \sqrt{1/T} * \Sigma u^2$ with the integration in the range from $0 \div T$, and in the memory there are put the values $Mem1 = \Sigma u^2$ and $Mem2 = u_0^2$

- In the second step the integration range is moved to $1 \div T+1$, then the effective value is calculated according to the relation $U_{ef(1 \div T+1)} = \sqrt{1/T} * (Mem1 - Mem2 + u_{T+1}^2)$ and to the memory there will be put the values $Mem1 = (Mem1 - Mem2 + u_{T+1}^2)$ and $Mem2 = u_1^2$

- In the next steps the calculation is repeated the same way as in the second step, considering the fact that the integration range is just shifted $2 \div T+2$, $3 \div T+3$ etc.

In order to obtain the exact effective value in particular moment, the calculated effective values must be overcalculated in a particular interval according to the relation $U_{efx} = \Sigma U_{ef(n \div T+n)} / T$ where $n = x-T+1 \div x$

The process of calculating of the active power P [W] is similar as when calculating the effective value, just with the difference that instead of Σu^2 there is calculated $\Sigma u * i$ The next derived electrical quantities are calculated in the same way as in the method used in the CALDEQ software.

4. Summary of conclusions - Comparing the different methods of calculating the derived electrical quantities

From the pictures No. 1, 3 and 4 it is possible to see an obvious difference between the ways of calculating in the graphical presentation of calculated values.

The other advantages of the 2nd and 3rd methods are e.g. showed when we want to find out the gradients of the changes of calculated electrical quantities. For example by deriving the calculated process of the impedance Z [Ω] according to the relation $dz_n = z_{n+1} - z_n$ we can calculate the process dZ/dt. From a process calculated in such a way we can see the tendency of the impedance decrease and so it is possible to analyse the intimation and impacts of the distancional electrical protections.
Calculated derived quantities, put into the graph, represent a step process.
At the values calculated by this method it is not possible to determine – follow the tendency of their change of

impedance is not possible to be determined by the relation $dZ = Zn + 1 - Zn$.
The combined method of the calculation enables a fast exact finding out of the gradient of the followed electrical quantity change.
By keeping the results of the calculations and by comparing the two results obtained one after another it is possible to create the starting function of the digital electrical protections.
This method can be used in the evaluating and active algorithms of overcurrent and impedancy digital protections. By a fast exact finding out of the gradient of the fault current change or the impedance of the protected object change it is possible to increase the reactive speed (rate) of these protections and in this way significantly limit the fault short-circuit energy.

References:

[1] SYNCHRONIZED SAMPLING AND PHASOR MEASUREMENTS FOR RELAYING AND CONTROL prepared by Working Group H-7 of the Relaying Channels Subcommittee A.G. Phadke, Chairman, B.Pickett, Vice Chairman (page 2 and 3)

[2] SYNCHRONIZED PHASOR MEASUREMENTS Theory and Implementation, Dr. Jaine De La Ree, Center for Power Engineering Virginia Tech., Workshop on Synchronized Phasor Measurements – Arlington, Virginia 1996