POWER SOURCE TYPE IMPACT ON THE OUTPUT SIGNAL OF PULSE ECT

Stefcho Georgiev Guninski

Dep. „Electrical Engineering”, Technical University of Sofia,
8, „Kl.Ohridski” blvd., 1756 Sofia, tel. (+359 2) 965 2318
e-mail: sgg@tu-sofia.bg

Abstract. *In the paper are investigated the differences between the output signal of pulse eddy-current transducer when it is supplied with ideal voltage source and ideal current source in two types of periodical pulses. It is considered parametric transducer when the controlled parameter is specific electrical conductivity of the conductive ferromagnetic controlled object. It is shown the difference in the form of output signal and based on these results are increased the number of its information parameters in different type of supplying and in different form of input pulses.*

Keywords: *pulsed ECT, voltage driven, current driven*

1. INTRODUCTION

The output signal of the eddy current transducers (ECT) depends mainly on the shape, dimensions and electrophysical parameters of the controlled object (CO). The signal depends equally on the shape, dimensions and electrophysical parameters (especially in the presence of magnetic circuit) of the ECT and mostly on the parameters of the field current generated by it. The output signal also depends on the relative location of the ECT and the CO.

In the classic theory of electromagnetic control most often the excitation winding of the ECT is supplied from *ideal **current** source.* The change of the output signal type is insufficiently studied when the supply is from *ideal **voltage** source*. The occasional studies [1] consider the case of stationary *sinusoidal mode*. The recent intensive development of the pulse methods for non-destructive control bring up the issue of the difference in the type of the output signal of the transducer in case of pulse supply from *ideal voltage source* and *ideal current source*. The subject of this study is a *parametric ECT* (i. e. only <u>one</u>-coil) supplied with the two types of ideal sources (Fig. 1 – of voltage and Fig. 2 – of current), characterised with EMF (electromotive force) and EMC (electromotive current) that change periodically and are single-pole with triangle (Fig. 3) and rectangular (trapezoidal) (Fig. 4) shape. In the studied example in both cases the frequency is f = 2.5 kHz, and the mark-to-space is 0.5. The fronts of the rectangular (trapezoidal) pulse are 1 μs, i. e. 0.5 % of its duration. The controlled object is non-ferromagnetic, the ECT is without ferromagnetic core, which enables the latter to be modelled in the equivalent circuit with linear resistor R_{ECT} and linear inductance L_{ECT} (Fig. 1 and Fig. 2).

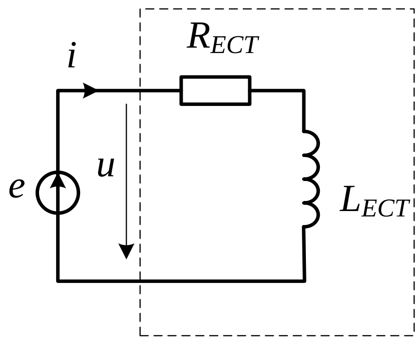

Fig. 1

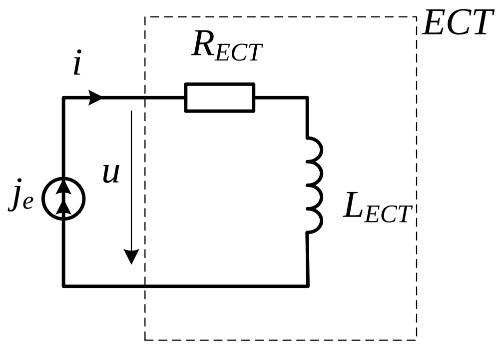

Fig. 2

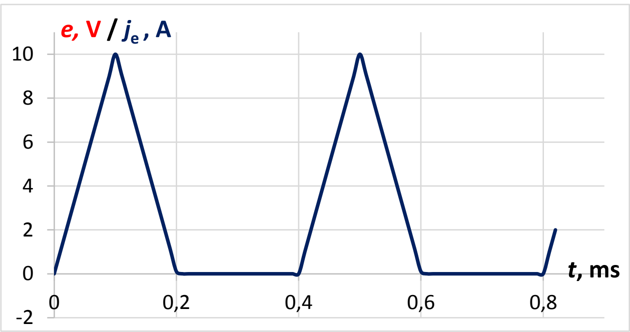

Fig. 3

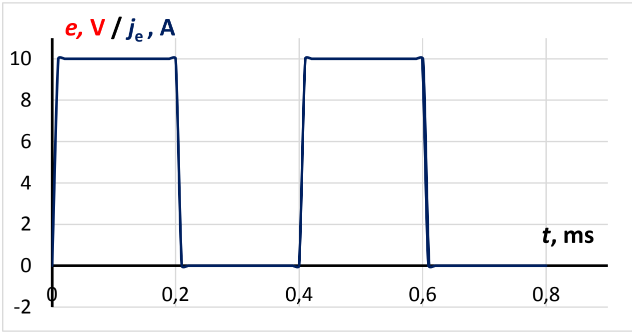

Fig. 4

2. SETUP OF THE PROBLEM

A. *Output signal*

The classic theory of the non-destructive control [2] considers the complex *imported* impedance Z_{BH} of the coil, as output signal of the parametric ECT, because the generally considered modes are sinusoidal, the supply is from ideal current source:

$$Z_{ECT} = Z_0 + Z_{im}\,, \tag{1}$$

$$Z_0 = R_0 + j\omega L_0\,, \tag{2a}$$

$$Z_{im} = R_{im} - j\omega L_{im}. \tag{2b}$$

Of course the imported complex conductance may be introduced in case of supply from ideal voltage source.

$$Y_{im} = G_{im} - jB_{im}\,. \tag{3}$$

The main information parameters of the output signal in sinusoidal mode are the real and imaginary part of the complex representations or their module and phase. Their frequency is less used.

Fig. 5 shows the *normalized plan diagram* of **the relative imported complex impedance** $Z_{im}^{*} = Z_{im}/\omega L_0$ in case of supply from ideal current source and change of the specific electricity conductance of the CO from 0 to 1.10^6 MS/m, which is a fundamental relation in the theory of NDT. Fig. 6 presents the equivalent *normalized plan diagram* of the **relative imported complex admittance.**

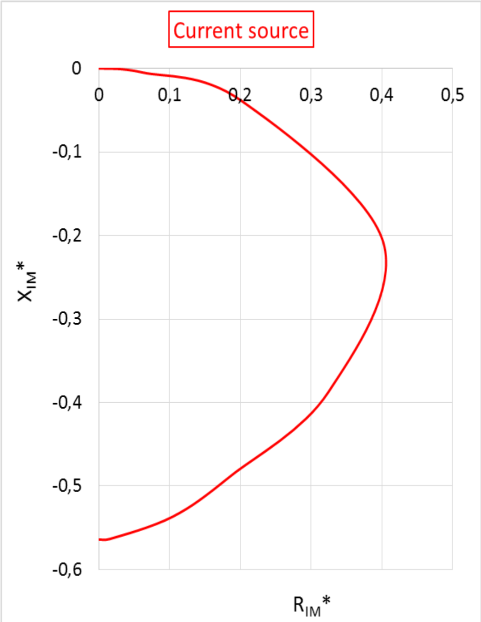

Fig. 5

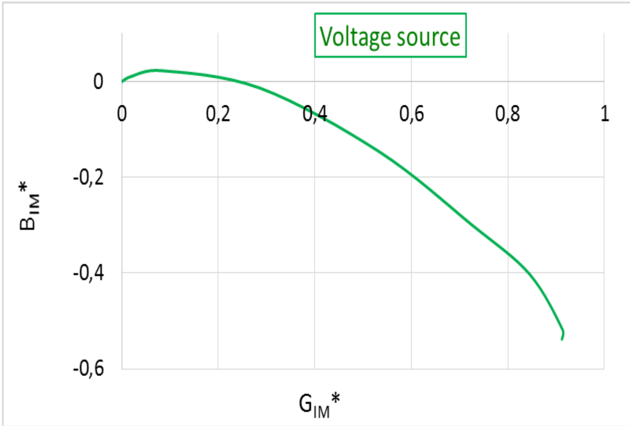

Fig. 6

Obviously in case of pulse modes this is not possible, therefore here the current through the transducer in case of supply from voltage source (Fig. 1) and the voltage at the terminals of the ECT in case of supply from current source (Fig. 2) will be considered as output signal. It shall be noted that these output signals by their nature coincide with the complex impedance (admittance) in case of the sinusoidal supply, but unlike them offer much more information parameters. They depend on the shape of the currents and voltages and most often are with extreme values, average or RMS values and phase ratios.

B. *Calculation model*

The controlled object is a homogenous upright circular cylinder. It is non-ferromagnetic and conducting with specific electric conductance γ, considered as the controlled (measured) value. ECT is a real three-dimensional cylinder coil, coaxial with the CO and is made of standard copper winding wire (Fig. 7).

The problem in case of supply from ideal current source is purely a “field” one, while in case of ideal voltage source the problem is mixed – Maxwell’s equations and the equations following Kirchoff’s laws shall be solved together. Both cases do not offer useful for direct application outcomes of analytic solutions – it is always necessary to apply, even partially, numerical methods. That is why it is very useful to apply modern software products that use numerical models (most often FEM) to solve the electrodynamic problem, enabling the inclusion of coils in electric circuits. In this case the product MagNet 7.4 [3, 4] is used, which involves creation of 3D models, performs analysis under non-stationary modes and enables inclusion of the elements of the model in various electric circuits.

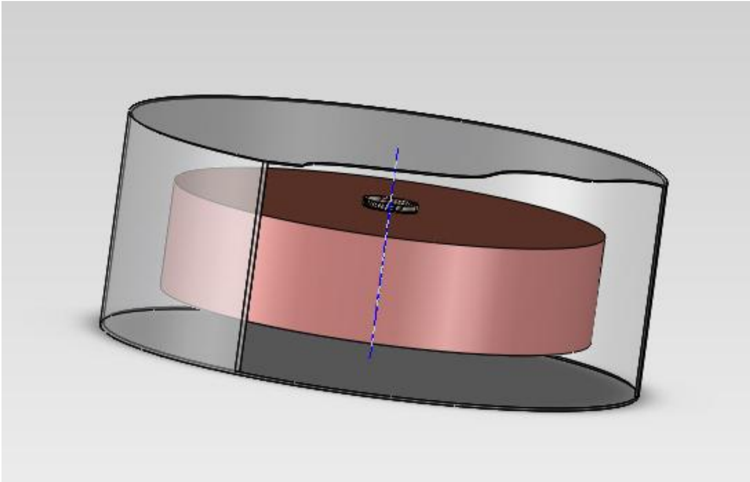

Fig. 7

3. RESULTS OF THE NUMERICAL EXERIMENTS

A series of numerical experiments are carried out with different type of the supplying source –current driven (Fig. 2) and of voltage driven (Fig. 1) and with two shapes of the supplying pulses – triangular (Fig. 3) and rectangular (Fig. 4) with eight values of the specific electric conductance: problem P1 – γ = 0.01 MS/m, P2 – γ = 0.2 MS/m, P3 – γ = 1 MS/m, P4 – γ = 8 MS/m, P5 – γ = 50 MS/m, P6 – γ = 300 MS/m, P7 – γ = 1500 MS/m, P8 – γ = 20000 MS/m.

- Supply from ideal current source in case of pulses with:

  – Triangular shape

Fig. 8 and Fig. 9 show the grafs of the output voltage.

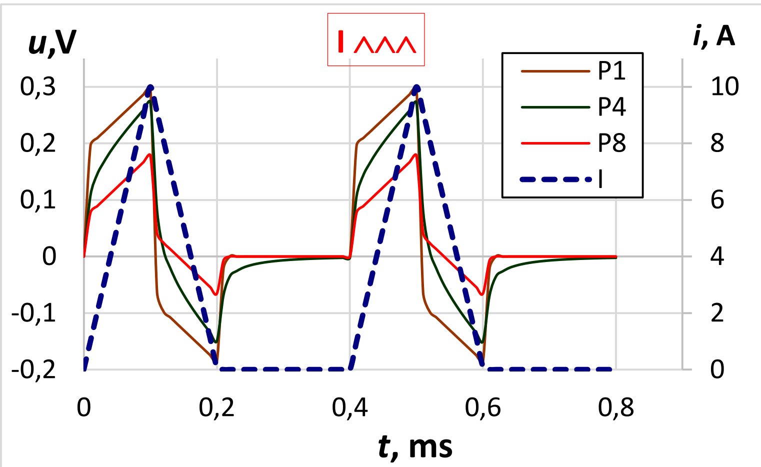

Fig. 8

Fig. 10 shows the dependence of the extrema of the output voltage (in absolute terms) on the specific electric conductance.

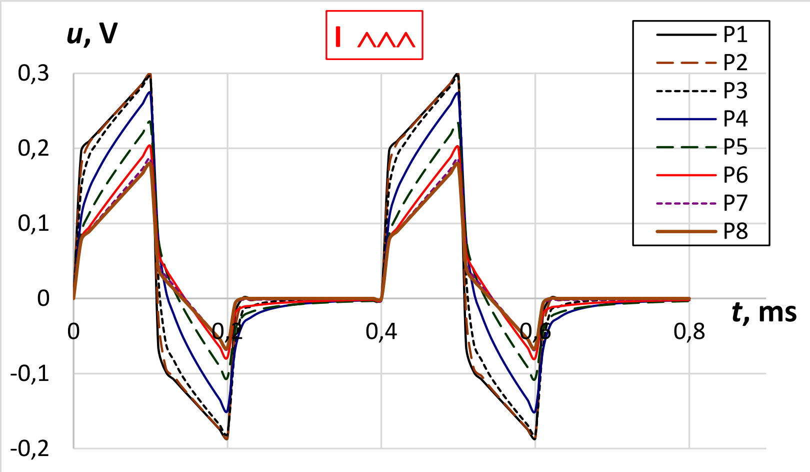

Fig. 9

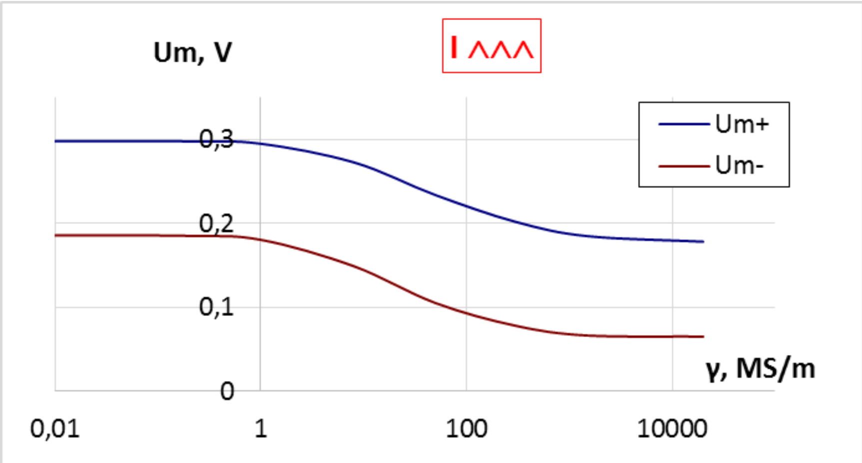

Fig. 10

– Rectangular shape

Fig. 11 and fig. 12 show the grafs of the output voltage.

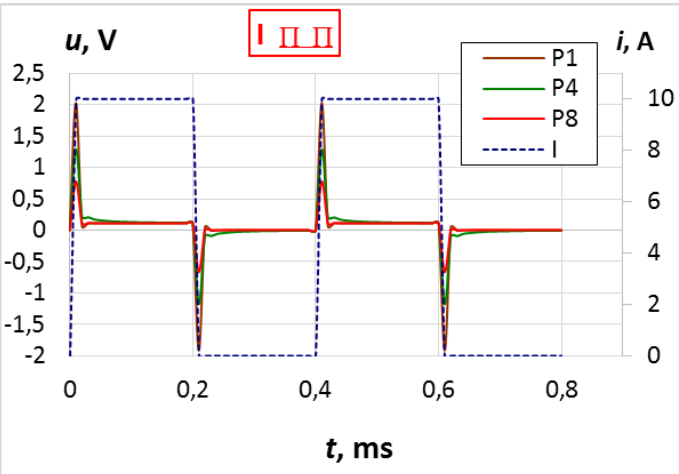

Fig. 11

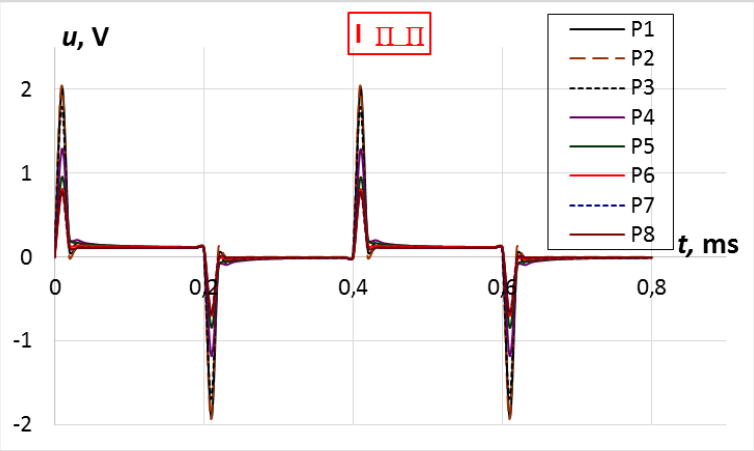

Fig. 12

Fig. 13 shows the dependence of the extrema of the output voltage (in absolute terms) on the specific electric conductance.

- Supply from ideal source of voltage in case of pulses with:
  – Triangular shape

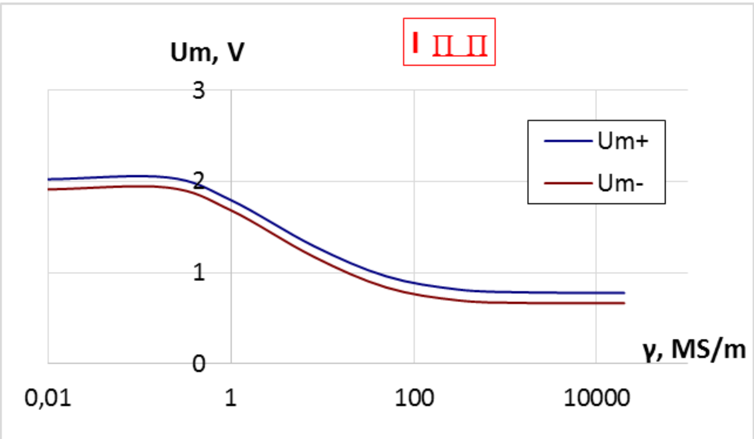

Fig. 13

Fig. 14 and Fig. 15 show the grafs of the output current.

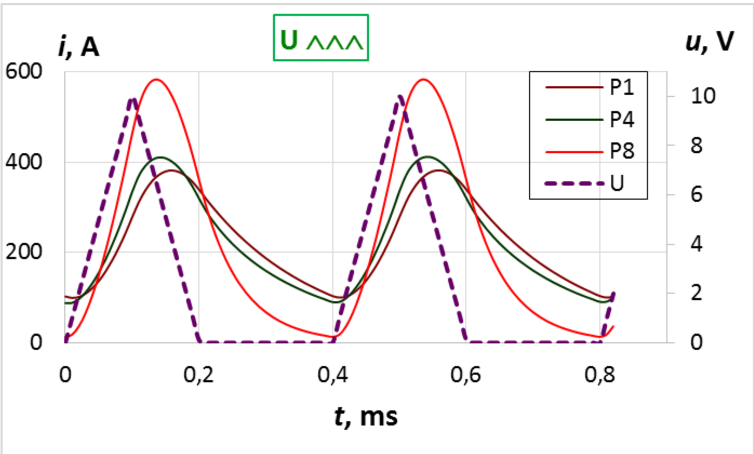

Fig. 14

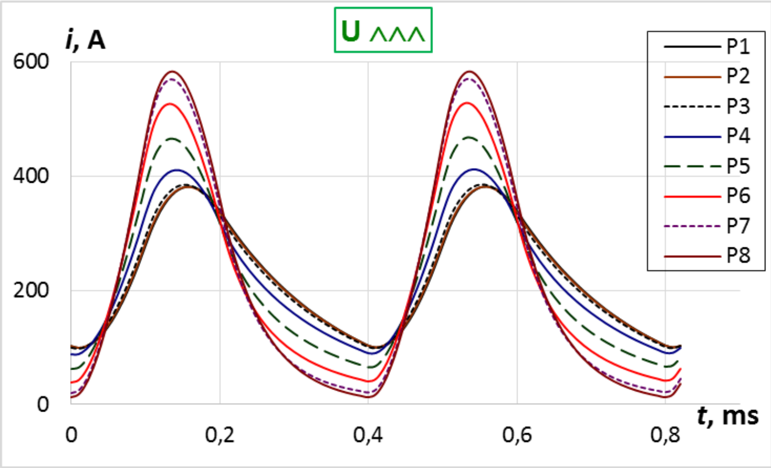

Fig. 15

Fig. 16 shows the dependence of the extrema of the output current on the specific electric conductance.

– Rectangular shape

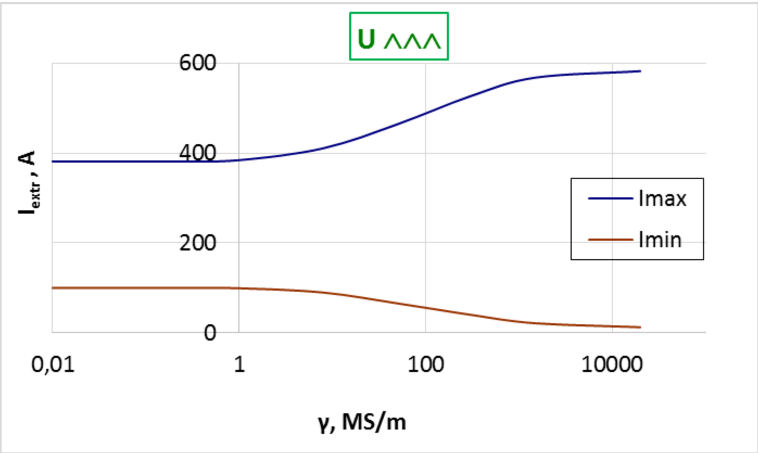

Fig. 16

Fig. 17 and fig. 18 show the grafs of the output current.

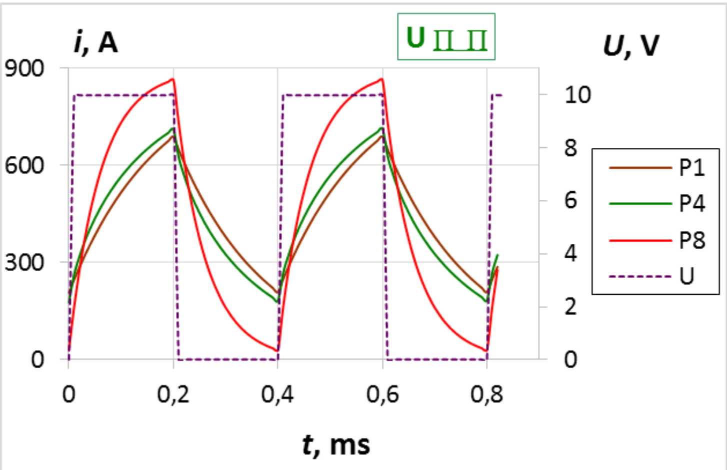

Fig. 17

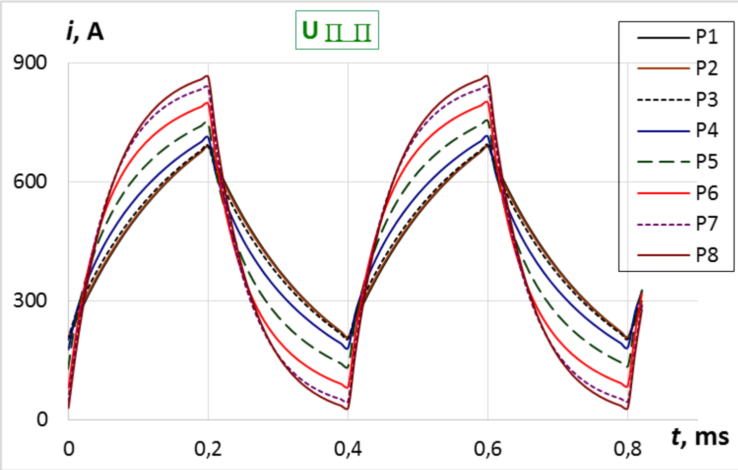

Fig. 18

Fig. 19 shows the dependence of the extrema of the output current on the specific electric conductance.

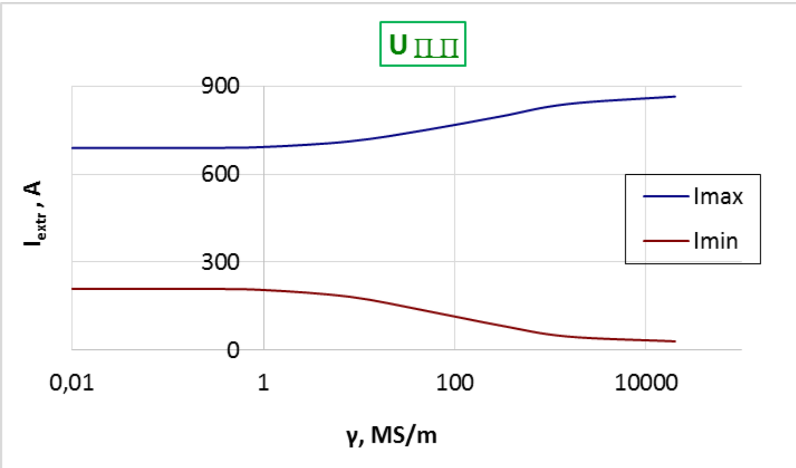

Fig. 19

4. CONCLUSIONS

- The shape of the output pulses with the two types of ideal sources differs substantially:
  - In case of current source with triangular pulses the output voltage is with the shape of *bipolar trapezoidal pulses* (Fig. 9) and with the increase of the specific electric conductance the negative part becomes *triangular*. In case of voltage source with triangular pulses, the output current is with the shape of *single-pole bell-shaped pulses* that do not reach zero (Fig. 14).
  - In case of current source with rectangular pulses, the output voltage is with the shape of *bipolar narrow peaked pulses* during the fronts of the field current (Fig. 11). In case of voltage source with rectangular pul-

ses, the output current is with the shape of *single-pole triangular pulses, which sides are exponents* that do not reach zero (Fig. 17).

- In case of supply from ideal voltage source with both output pulse shape, the average value of the output pulses is an appropriate information parameter, while in case of supply from ideal current source, the average (RMS) value of the output current is useful only for triangular pulses.
- **In all cases the extrema of the output pulses are an appropriate information parameter!** The character of their dependence on the specific electric conductance γ is similar in cases of different shapes of the output pulses.

The table presents the ranges, in which the sensitivity of the output signal towards the specific electric conductance is greater for the different cases.

Source	Pulse shape	Max sensibility to γ, MS/m	
		from, MS/m	to, MS/m
Current driven	triangular	1	100
	rectangular	0.5	120
Voltage driven	triangular	3	200
	rectangular	3	200

References

[1] Menana Hocine, Mouloud Feliachi, Contribution to the Modeling of a Voltage Driven Pulsed Eddy Current Sensor for the Characterization of Conductive Plates, Analog Integr Circ Sig Process (2011) 69: 75–80
[2] Tzvetkov D., Electromagnitna defektometria, S., Tehnika, 1981.
[3] www.infolytica.com
[4] 2D Tutorial, Preparing, Solving and Interpreting NDT Problems, Infolytica Corp., 2005.

Reviewer: Prof. PhD K. Brandisky