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Recognition of Fast Electromagnetic Transients in HV Overhead Lines

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Introduction

The modelling of the very fast electromagnetic transients in electric power system is important and rather complicated task especially when the goal deals with a problem of any recognition in the net. The modelling of the very fast transients let to achieve sufficient precision in the net with distributed parameters, acceptable linearization of nodes parameters and to simplify algorithms by using efficient digital filters.

Modeling of fast processes has certain advantages: is more informative, compare to modeling when transient components completely or partially are less disturbed by electric network non-linear parameters, it has better rectilinear property in optimization of network identification [6, 10].

The length of electrical lines in a network and a velocity of electromagnetic waves arbitrate recording time. Usually it takes from some microseconds till some hundreds microseconds. But the most informative data traces on the front of recorded currents or voltages. It lets sometimes to use enough short recordings and to get acceptable recognition.

Accidental emergency earth fault because of large initial voltage value alternations in power distribution networks creates sharp transient process, which analysis permits to perform earth fault spotting and recognition of certain specific electric network peculiarities. It is purposeful to obtain specific resistances of soil under the electric network line, capacity values of connected to the line equipment, also network map configuration diagram.

Simplification of operating electric network by external electric network structure‘s, elimination of non-linearity problem by registering electromagnetic transient process with high discrete frequency, optimization of different electric network parameters, allows to solve accidental emergency earth fault recognition task.

Initial processes are formed by fast or slow variation of damping components. More components are taken into consideration during analysis, fullness process picture is obtained. Model of fast electromagnetic processes is such, where fast damping components are reflected.

Object of this work is to analyze overhead lines parameters of 10 kV and 20 kV electric network, and to evaluate influence of transient process discrete registration frequency.

HV Line‘s Models Parameters

Power overhead line parameters (constructional and electrical) matrix main and sidelong diagonals’ elements have different values. Therefore application of widely known transient and stationary processes modeling methods with symmetrical or Clark‘s components is fast processes analysis in received sequences may reduce recognition accuracy.

If conventional processes transformations into sequences methods are used, depth flow of electric fields in deep soil under overhead lines reduces accuracy even more. Matrix of inductive specific parameters of depth flow become non similar to matrix of capacitive parameters, and surface traveling electromagnetic waves are supplemented by electromagnetic fields scattering according to transversal direction line [1].

Electric fields of transient processes in ground soil change depth and form depending on how quick damp the components of electric field’ different frequencies. In model in gives praise to alternation of line’s wave parameters. Approximating model to the line‘s fast processes is necessary to achieve proper estimation of these parameters.

It is purposeful sequences of fast electromagnetic processes transform into adopted to typically used brands of overhead lines. In some cases for different overhead lines might be necessary have the use of only specific for these lines character transformations and line‘s equations.

Composing earth faults location in distribution network recognition model, examination in 10 kV and 20 kV networks are needed. Mentioned voltage distribution networks are most problematic, as they are widely branched, and in most of the cases are compensated. In such networks recognition of earth fault using conventional measurements of stationary operational voltages and currents are practically impossible.

The idea of injection of outsource signal to transmission line is used for the third method. The generation of outsource signal is synchronized with registration of received travelling wave. Then the time difference is calculated between generated signals and reflected from fault. This method has disadvantage which is pronounced then the fault is short i.e. the fault duration is less then travelling wave propagation time from fault to busses and back. Furthermore, another disadvantage could be seen due to the line wave channel heterogeneous [7].

For modeling of fast electromagnetic processes base for time dimension is taken D‘Alambert equations [4]. Idealizing processes only on waves‘ surface line bases, and eliminating dissipation’s phenomenon of scattering of electromagnetic field in the overhead line‘s wires and soil, equations in symmetrical and Clark sequences will take following form:

$$\begin{cases} U + wI = 2U^{+}, \\ U - wI = 2U^{-}, \end{cases} \tag{1}$$

here $\mathbf{U}^{+}$ and $\mathbf{U}^{-}$ – columns of matrix values of voltage traveling and reflected waves‘ sequences; **U** and **I** – voltage and current sequence vectors flowing into the wave‘s refraction point in the line; w – diagonal matrix of wave impedance sequences.

On the basis of Clark‘s transformation method received waves equations (1) are suitable for slow process analyze, when investigating electromechanical transient processes, that generates nonsymmetrical short circuit connection in the network or in the determinant work studies where precise results are not so important.

However in order to receive not perverted electromagnetic process picture as recognition of registered processes, is necessary to seek higher precision and adequacy.

Recognition of fast processes covers alternating parameters which duration is only some tenth microseconds; therefore for precise modeling frequency band of over tenth kilohertz is requested. In this part of spectrum modal matrix dependency upon frequency is smaller. In distribution electrical network in most of the cases line wires configuration is geometrically similar, matrix of line‘s specific electric parameters are similar as well (modal matrixes are homogeneous). These two reasons permitted to find a line equation that reflects more precise and more exact to real processes.

To determine the pole, which is close to earth fault, possibly accurate measurements are needed, and is necessary more adequate modeling within high frequency band, frequency band over 100 kHz. Processes in low frequency band are less informative and therefore lower accuracy of analysis. Favor is such, that in high frequency area elements of $\mathbf{N_L}$ matrix are less dependent from frequency. Such a conditional invariance regarding frequency permits to unify, simplify and get more accurate model structure. In the table 1 and table 2 is given alteration of matrix $\mathbf{N_L}$ dependency from frequency change, in cases of various soil resistance and overhead line wires configurations. As we can see in the tables, when frequency increase 100 times from 100 Hz, norm changes about 40 percent, when in the frequency area, when frequency increase o 100 times, from 0,1 MHz - change is about 12-20 percent.

Table 1. N_L matrix norm dependency from frequency (kHz range)

Line configuration	Soil spec.resistance Ωm	Process frequency		
		0,1	1,0	10
		kHz		
10 kV Pyramid type	100	25,58	21,64	18,32
	300	27,15	23,19	19,71
	1000	28,89	24,93	21,35
	3000	30,49	26,54	22,90
20 kV Raven type	100	25,03	21,09	17,80
	300	26,60	22,63	19,17
	1000	28,34	24,37	20,80
	3000	29,94	25,97	22,34

Data presented in the tables are found for typical pole‘s spans and standard line‘s wire configurations, using Euclid norms calculation method

$$\text{norm} = \sqrt{\sum_{\forall i,k} \left| \boldsymbol{N_L}(i,k) \right|^2} . \tag{2}$$

Table 2. N_L matrix norm dependency from frequency (MHz range)

Line type	Soil spec. resistance, Ωm	Process frequency		
		0,1	1,0	10
		MHz		
10 kV Pyramid type	100	15,83	14,42	13,87
	300	16,85	14,95	14,06
	1000	18,21	15,79	14,41
	3000	19,60	16,82	14,93
20 kV Raven type	100	15,36	14,02	13,51
	300	16,36	14,51	13,68
	1000	17,69	15,32	14,01
	3000	19,06	16,32	14,50

Soil resistance has also an influence to diagonalization accuracy. Fig. 1 shows diagonalization‘s errors curve. This curve is obtained when soil resistance alters within wide limits at a $f = 23$ kHz frequency value, and diagonazation is done by real numbers‘ basic frequency modal matrix $\tilde{\boldsymbol{T}}_{\boldsymbol{u}} = \mathrm{real}(\boldsymbol{T}_{\boldsymbol{u}})$ or $\tilde{\boldsymbol{T}}_{\boldsymbol{i}} = \mathrm{real}(\boldsymbol{T}_{\boldsymbol{i}})$. It is taken into account most non homogeneous case of overhead line‘s configuration (horizontal).. As drawing shows – within the specific resistance range up to 3000 Ωm (it coincides with real conditions) the biggest error is at high resistance values (near 3000 Ωm). Therefore in order to define propagation‘s constant diagonalization quality with admissible modal matrix $\tilde{\mathbf{T}}_{\mathbf{u}}$ or $\tilde{\mathbf{T}}_{\mathbf{i}}$, calculations performed at specific soil resistance 3000 Ωm.

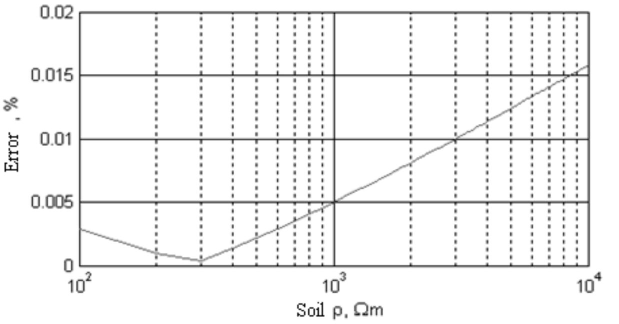

Fig. 1. Diagram of propagation constant matrix diagonalization‘s errors dependency upon soil resistance

Model Structure’s Aspects

Equation of wave lines (1) does not reflect phenomenon of dissipation and dispersion of electromagnetic waves scattering in the line. Together with the variation of harmonic process frequency, also alter propagation‘s constants and wave impedance. Higher frequency is lower is absolute value of propagation‘s constants and wave impedance. Influence of such alteration within the whole complex of multiharmonics, should be properly reflected in line‘s model structure

Diagonal matrix of wave impedance could be found by following expression (2)

$$\begin{cases} \mathbf{w} = \sqrt{\frac{\mu}{\varepsilon}} \left(\mathbf{T}_{\mathbf{u}}^{-\mathbf{1}} \mathrm{real}\left(\left(\mathbf{N}_{\mathbf{L}} + \mathbf{N} \right) \mathbf{N}^{-1} \right) \mathbf{T}_{\mathbf{u}} \right)^{-0.\,5}, \\ \mathbf{T}_{\mathbf{u}}^{-\mathbf{1}} \mathrm{real}\left(\mathbf{N}_{\mathbf{L}} + \mathbf{N} \right) \mathbf{T}_{\mathbf{i}} . \end{cases} \tag{3}$$

In order to define the influence of imaginary part of diagonal wave impedance matrix to the distribution of currents and voltages in the line‘s wires, examination is carried out changing waves impedance by their absolute values. Errors are estimated when matrix of absolute values are find by the expression (2).

As illustration in the drawing Fig. 2 is indicated curves of diagonal wave impedance dependency upon frequency, that are received using adequate modal matrix detected at the 23 kHz frequency value. Cases reflect typical alteration character of distribution electrical network lines‘ waves impedance change for whole three sequences, when wire configuration is: isosceles triangle („pyramid“) - curve No.1 and parallel to ground surface – curve No. 2.

As illustration in the Fig. 2, 1st and 2nd sequence wave impedance in the frequency range from 10 kHz are constant. This is vivid example of advantage of fast process analysis, as wave impedance is not needed.. Alteration character of 3rd sequence wave impedances is homogeneous nature; therefore approximation according to one standard curve is less complicated. It is clear, that in order to achieve higher analysis accuracy, might by purposeful to perform correction of sequence wave impedance in time dimension by functions‘ convolution method.

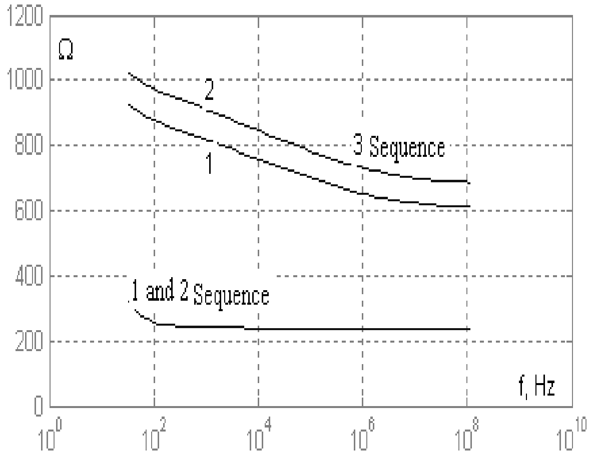

Fig. 2. Sequence wave impedance real part dependency upon frequency; 1st and 3rd sequence curves – when wire configuration is isosceles triangle, 2nd curve of 3rd sequence – when wire configuration is parallel to ground surface

Conclusions

Recognition technology is based on comparison carried out by one or another kind where registered or measured electrical parameters are collated with obtained in the model or obtained using modeling mathematical expressions. The more model exhaustively and accurate reflects existing real processes in the electrical network, the more recognition is better and accurate. Therefore it is important that model shall repeat process as adequate as possible.

References

1. **Gudžius S., Markevičius L. A., Morkvėnas A.** Recursive method to examine electromagnetic transient processes in cable network // IV Sympozjum, Metody matematyczne w elektroenergetyce (MMwEE’98). – Zakopane, 1998. – P. 235– 244.
2. **Gudžius S., Markevičius L. A., Morkvėnas A.** The research of overvoltages arresters efficiency in high voltage substation // XI International Conference on Electromagnetic Disturbances (EMD’2001). – Bialystok: Bialystok Technical University, 2001. – P.3–6.
3. **Gudžius S., Markevičius L. A., Morkvėnas A.** Viršįtampių ribotuvų darbo sąlygų tyrimas izoliuotos neutralės tinkle // Energetika. – Vilnius: Academia. – 2001. – P. 21–26.

4. **Gudžius S., Markevičius L. A., Morkvėnas A.** Elektromagnetinių pereinamųjų procesų modeliavimo izoliuotos neutralės tinkle ypatumai // Tarptautinės konferencijos (Elektros ir valdymo technologijos‘2006) pranešimų medžiaga. – Kaunas: Technologija, 2006. – P. 161–166.
5. **Gudžius S., Markevičius L. A., Morkvėnas A., Markevičius L.** The spotting reliability of the transient processes during one phase to ground fault // Proceedings of the XVII International Conference on Electromagnetic Disturbances (EMD’2007). – Bialystok: Bialystok Technical University, 2007. – P. 183–186.
6. **Greitans M., Hermanis E., Selivanovs A.** Sensor Based Diagnosis of Three–Phase Power Transmission Lines // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 6(94). – P. 23–26.
7. **Siozinys V.** Transmission Line Fault Distance Measurement Based on Time Difference between Travelling Wave Reflection and Refraction // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 2(98). – P. 25–28.
8. **Czapp S.** Comparison of Residual Current Devices Tripping Characteristics for Selected Residual Current Waveforms // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 4(100). – P. 7–10.
9. **Rafajdus P., Bracinik P., Hrabovcova V.** The Current Transformer Parameters Investigation and Simulations // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 4(100). – P. 29–32.
10. **Ciufudean C., Filote C., Larionescu A.** New Digraph Models for Diagnosis of Electric Cables // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 6(94). – P. 65–68.

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This article is about recognition of fast electromagnetic transients in HV overhead lines. The modeling of the very fast electromagnetic transients in HV overhead lines is important and rather complicated task especially when the goal deals with a problem of the recognition of the fast electromagnetic transients in the electric power network. Precise modeling of the fast electromagnetic transients in the overhead distribution lines helps to define more precise processes characteristics, and create more accurate recognition models. The paper describes the results of the modeling of the fast electromagnetic transients in HV overhead power lines and discusses the ways of its application for the recognition of the fast electromagnetic transients. Ill. 2, bibl. 10, tabl. 2 (in English; abstracts in English and Lithuanian).

S. Gudžius, A. Morkvėnas, L. A. Markevičius, R. Miliūnė, L. Markevičius. Spračių elektromagnetinių procesų atpažinimas aukštosios įtampos orinėse elektros perdavimo linijose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 1(107). – P. 103–106.

Straipsnyje nagrinėjami spartūs elektromagnetiniai procesai, vykstantys aukštosios įtampos orinėse perdavimo linijose. Sparčių elektromagnetinių procesų modeliavimas orinėse elektros perdavimo linijose yra svarbus ir sudėtingas uždavinys, ypač kai reikia atpažinti elektromagnetinius procesus, vykstančius elektros energijos perdavimo tinkluose. Tikslus šių procesų modeliavimas orinėse elektros energijos perdavimo linijose įgalina sudaryti tikslesnes pereinamųjų procesų charakteristikas ir sukurti tikslesnius modelius spartiems elektromagnetiniams procesams atpažinti. Straipsnyje pateikti greitų elektromagnetinių procesų modeliavimo aukštosios įtampos orinėse elektros perdavimo linijose rezultatai ir suformuluoti jų pritaikymo elektromagnetinių procesų atpažinimo uždaviniui spręsti principai. Il. 2, bibl. 10, lent. 2 (anglų kalba; santraukos anglų ir lietuvių k.).