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Numerical simulation and analytical model of electrical arc impedance in the transient processes

Abstract. *In the paper are derived analytical expressions for calculation of values of transient resistances of electric arc in the case of interphase short circuits and also is performed numerical MATLAB simulation of electric arc in transient process. Modelling and simulation of electric network and arc was conducted in MATLAB Simulink surrounding, within the mathematical program MATLAB for simulation of transient processes. Empirical approach based on experiment was used in forming of analytical model of arc. Analysis was performed for two-phase and three-phase short circuits in the network, and real parameters of arc impedance are presented in Tables. Model has practical application because all parameters used in analysis can be obtained by measurement.*

Streszczenie. *W artykule opisano sposób wyznaczenia wyrażenia określającego wartości chwilowe rezystancji łuków elektrycznych w przypadku zwarć międzyfazowych w sieci elektroenergetycznej. Przedstawiono wyniki badań symulacyjnych w programie Matlab. Stworzono empiryczny model łuku elektrycznego, którego wszystkie parametry mogą zostać uzyskane w pomiarach. (**Symulacje i analiza modelu impedancji łuku elektrycznego w stanach nieustalonych**).*

Keywords: electrical arc, short circuits, transient processes, numerical and analytical procedure.
Słowa kluczowe: łuk elektryczny, zwarcie, stan nieustalony, procedury numeryczne i analityczne.

Introduction

In the analyses of transient processes usually is presumed the resistance of electric arc, which has non-linear active character, and that the value of its inductivity equals to zero. Therefore, the assumption is reasonable about the simultaneous passage of currents and voltages through zero value and about active character of arc resistance.

In "Black box" model, the arc is described by a simple mathematical equation and obtained the relation refers to arc conductance, which can be obtained by measurement of parameters such as voltage and current of the arc. Black box model is not suitable for observation of open circuit, but is very reliable for simulation of occurrences in electric arcs circuits in the studies of electric networks. Although it is based on the model of physical conditions, it is just a mathematical model. Black box model is consisted of one or two differential equations. Model parameters can change according to different functions from different data. According to tables used, the accurate parameters of black box model are obtained.

Cassie model refers to study of electric arc conductance behaviour at high currents in time intervals which correspond to plasma temperatures that are higher than 8000 K.

The Mayr model describes the arc conductance in the cases when currents close to value zero. Mayr argues that arc channel has cylindrical shape with the constant diameter. Other black box models capable of simulating thermodynamic occurrences at breaking of the arc channel are the Avdonin model, the Hochrainer model, the Kopplin model, the Schwarz model, and the Urbanek model [1, 2].

All models show that at currents higher than I = 100A, gradient of electric arc voltage has value grad(E)=15$Vlcm$ and the value is in invert ratio to values of electric current. Arc model has non-linear electric conductance.

The classical black box models are the Cassie model and the Mayr model. Model Cassie & Mayr with generalized equation has universal character. In its general form, the momentary arc conductance [$g \leftrightarrow R$ = R_a, R = R_l] is a function of the parameter of the channel with plasma, from which energy is transmitted to surrounding at the same time by convection and radiation.

$$(1)\quad g = F\left(P_{in}, P_{our}, t\right) = \frac{i_{arc}}{u_{arc}} = \frac{1}{R}; \Rightarrow R = R_a = R_l = \frac{u_a}{i_a}$$

where: P_{in} – the power supplied to the arc plasma channel, P_{our} – the power transmitted through, t – time, i_{arc} – the instantaneous value of arc current, u_{arc} – the instantaneous value of arc voltage, R = R_a, R = R_l – index (l) translate in Serbian language word electrical arc = luk = arc(english)] – the instantaneous value of arc resistance.

Numerical procedure according to Van der Sluis method

Before the calculation, the Simulink system is initialized, then calculation is performed according to the model of eclectic circuit condition. The sample RLC circuit, which shall be used in this paper as the power system blockset (PSB) is presented on Fig. 1.a.

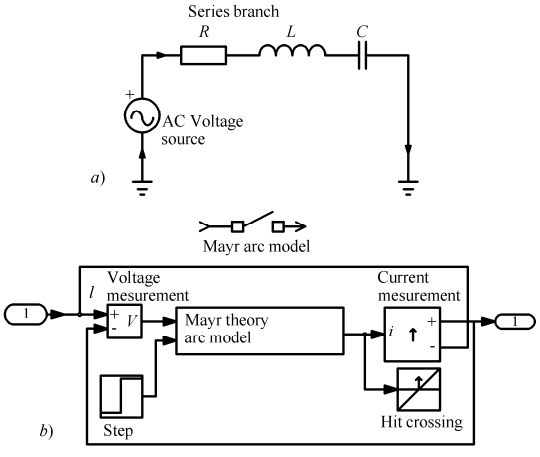

Fig.1. a) Sample RLC circuit in the MATLAB PSB, b) Implementation of the Mayr arc model in Matlab Simulink/Power System Block-set (PSB), [2]

It is important to note that the arrows on Fig. 1.b. do not indicate causes and consequences of creation of value in Simulink block diagram. The arc impedance can be modeled through voltage control of current resources. This