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Improvement of estimation of surge arrester parameters by using Modified Particle Swarm Optimization

M. Nafar [a,*], G.B. Gharehpetian [b], T. Niknam [c]

[a] Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] Department of Electrical Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran
[c] Department of Electrical and Electronics Engineering, Shiraz University of Technology, Shiraz, P.O. 71555-313, Iran

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ABSTRACT

Metal Oxide Surge Arrester (MOSA) accurate modeling and its parameter identification are very important aspects for arrester allocation, system reliability determination and insulation coordination studies. In this paper, Modified Particle Swarm Optimization (MPSO) algorithm is used to estimate the parameters of surge arrester models. The convergence to the local optima is often a drawback of the Particle Swarm Optimization (PSO). To overcome this demerit and improve the global search capability, Ant Colony Optimization (ACO) algorithm is combined with PSO algorithm in the proposed algorithm. The suggested algorithm selects optimum parameters for the arrester model by minimizing the error among simulated peak residual voltage values given by the manufacturer. The proposed algorithm is applied to a 120 kV MOSA. The validity and the accuracy of estimated parameters are assessed by comparing the predicted residual voltage with experimental results.

1. Introduction

Lightning and switching overvoltages in power systems are very common causes of interruptions [10–12]. The Metal Oxide Surge Arresters (MOSAs) are extensively used as protective devices against lightning and switching over voltages. Proper voltage–current characteristics, ignorable power losses, high level reliability in the operation time, high speed response to overvoltages and long life time are some advantages of MOSAs. Accurate modeling and simulation of their dynamic characteristics are very important for arrester allocation, system reliability assessment and insulation coordination studies [1–16]. For switching studies, MOSAs can be modeled by their nonlinear V–I characteristics [1,2]. However, such a presentation would not be appropriate for fast front transients and lightning surge studies; since dynamic characteristics obtained from MOSA show that voltage across the surge arrester increases as the time-to-crest of the arrester current decreases and the voltage of the arrester reaches a peak before arrester current reaches its maximum [1]. Typically, the residual voltage of an impulse current having a front time of 1 μs is 8–12% higher than that of predicted for an impulse current having a front time of 8μs. The residual voltage of longer time-to-crests between 45 and 60μs, is 2–4% lower than that of a 8μs current impulse [5–7]. This dynamic behavior requires a more sophisticated model for fast front waves. In order to reproduce the MOSA dynamic characteristics, several studies have been focused on the modeling and simulation of MOSAs [1–10]. IEEE, Pinceti and Fernandez models are the main models of surge arresters that have been presented to simulate the dynamic behavior of surge arresters. These models have different parameter estimation procedures. It is very often difficult to identify the dynamic model parameters from the available data [1–14]. In recent years, different procedures have been presented for estimating the parameters of all models [6–10]. In [7], a numerical method has been proposed for estimating the parameters of three mentioned models. New procedures, using heuristic algorithms, have been proposed to determine the best parameters of MOSAs models in Ref.[8 and 9]. These methods are based on the comparison of simulation results of residual voltages and the results of 8/20μs experimental measurements. Proposed methods of Ref. [7–9] are general and can be applied to all models. But, they need measurement results obtained under 8/20μs impulse test, which are not always available and reported in datasheets. To overcome this problem, a procedure has been presented in [10], which matches the peak of the discharge voltage obtained from 8/20μs impulse current. In this paper, it is shown that the comparison between the simulated peak residual voltage

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* Corresponding author. Tel.: +98 917 3018583; fax: +98 728 3311172.
E-mail address: m.nafar@srbiau.ac.ir (M. Nafar).

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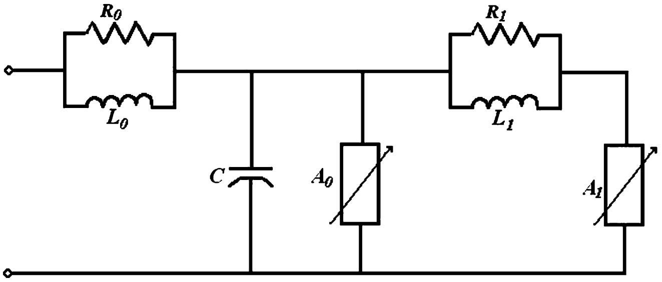

Fig. 1. IEEE model.

and the value given by the manufacturer under 8/20μs impulse test is not a major index. For estimating the parameters of surge arrester models, a new objective function based on the results of 8/20μs and 1/20μs impulse tests is proposed in this paper. The transient models of MOSA are simulated using ATP-EMTP. The results of simulations are applied to a developed program, which is based on MPSO algorithm and can determine the parameters of different models. The validity and accuracy of estimated parameters are assessed by comparing the predicted residual voltage with experimental results. Good agreement of results verifies the ability of the proposed algorithm for estimating surge arrester parameters.

Two main contributions of this paper are listed, as follows:

I: Proposal of a novel general method, based on a new objective function, for estimating the parameters of MOSA models.
II: Presentation of a new and modified evolutionary optimization algorithm based on combination of ACO and PSO algorithms.

2. Surge arrester transient models

Several surge arrester models have been suggested to describe the transient behavior of surge arresters [1–3]. In this section, the most important models are investigated.

The model, shown in Fig. 1, has been proposed by IEEE WG 3-4-11 [1]. An iterative trail and error procedure has been proposed to determine the model parameters. The starting values for the parameter estimation procedure have been determined considering the height and the number of arrester columns. Also, the nonlinear V–I characteristics of A_0 and A_1 could be estimated using values given in Table 1 [1].

The model, shown in Fig. 2, has been proposed by Pinceti. The calculation method of inductances for this model has been presented in [2].

Table 1
V–I characteristics for A0 and A1 (V_{10} is the discharge voltage (in kV) for a 10 kA, 8/20μs impulse current).

Current (kA)	Voltage (per unit of V_{10})	
	A_0	A_1
0.01	0.875	–
0.1	0.963	0.769
1	1.050	0.850
2	1.088	0.894
4	1.125	0.925
6	1.138	0.938
8	1.169	0.956
10	1.188	0.969
12	1.206	0.975
14	1.231	0.988
16	1.250	0.994
18	1.281	1
20	1.313	1.006

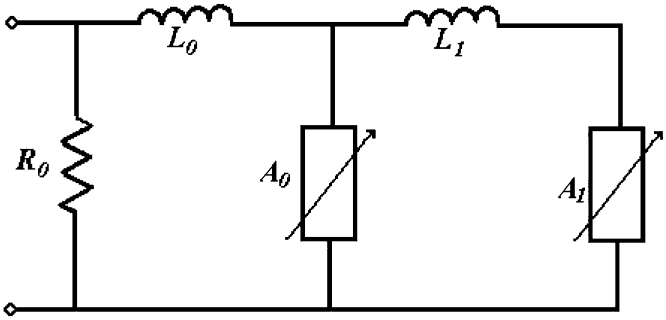

Fig. 2. Pinceti model.

In [3], Fernandez et al have presented other model for surge arresters. This model is shown in Fig. 3. In this model, it is assumed that the ratio (γ) of currents I_0 to I_1 through A_0 and A_1, respectively, remains constant all over the voltage range of their protection characteristic and the percent voltage increase between input terminals depends only on the inductance, L_1. Based on these assumptions, an iterative trial and error procedure has been proposed, to determine the model parameters. The details of this method have been presented in [3].

The models of Pinceti and Fernandez are based on the IEEE model. But, they are different in the parameter estimation procedure. They use the electrical characteristic data, obtained from the datasheet of manufacturers.

3. Objective function

Different parameter estimation procedures have been proposed for each surge arrester model. These procedures do not always result in the best parameters, but they can provide a good estimation (a starting point) [1–10]. It should be noted that these procedures and their applications are limited to the above mentioned models. In recent years, different solutions have been presented for estimating the parameters of MOSA models [6–10]. In [7], a numerical method has been proposed for identifying the parameters of three mentioned models. This method is based on the comparison of simulation results of residual voltages by the results derived from8/20μs experimental measurements. In this method, the parameters of MOSA models have been estimated by minimizing the following objective function:

$$F = \int_0^T W(t)[V(t,x) - Vm(t)]^2 \mathrm{d}t \tag{1}$$

where,

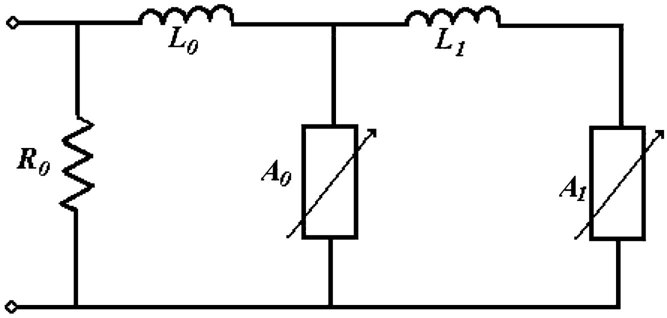

Fig. 3. Fernandez model.