Electric Power Systems Research 133 (2016) 87–92

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Comparison of ANN and finite element analysis simulation software for the calculation of the electric field around metal oxide surge arresters

Vasiliki Vita[a,*], Christos A. Christodoulou[b]

[a] A.S.PE.T.E.—School of Pedagogical and Technological Education, Department of Electrical and Electronic Engineering Educators, N. Heraklion, 141 21 Athens, Greece
[b] Department of Electrical & Computer Engineering, Democritus University of Thrace, 12 Vasillisis Sofias St., 671 00 Xanthi, Greece

ARTICLE INFO

Article history:
Received 7 March 2015
Received in revised form 16 October 2015
Accepted 29 November 2015
Available online 5 January 2016

Keywords:
Artificial neural networks
Electric field
Field meters
Measurements
Metal oxide surge arresters

ABSTRACT

Electric field values around metal oxide surge arresters is a very useful info that is used for issues related to the maximum field intensity in the arresters and for diagnostic tests related to the condition of the varistor and the existence of moisture or pollution on the insulation surface. The electric field around metal oxide surge arresters can be obtained either performing measurements using suitable equipment or through simulations using specialized software. An alternative to the existing methodologies for the calculation of surge arresters electric field is presenting in this paper using artificial neural networks (ANNs). A comparison in between the new method and the existing ones is performed in order to verify its accuracy. The developed ANN model can be a useful tool for electric utilities, laboratories and manufacturing companies dealing with medium voltage surge arresters that either face a lack of suitable measuring equipment or simulation software, or want to compare/verify their own measurements/calculations.

1. Introduction

Metal oxide gapless surge arresters constitute a very critical part of the lightning protection system of overhead transmission lines and substations. Surge arresters are installed between phase conductors and grounding system in order to guarantee that the developed overvoltages will not exceed the insulation withstand voltage of the equipment to be protected. The appropriate operation of the arresters is a crucial issue, since arresters are constantly stressed by the nominal voltage of the network; in addition, the discharge currents flowing through them downgrade their effectiveness.

The increase of the electric field around surge arrester contributes electrical designers to consider important factors affecting the maximum field intensity in the arrester. It is aimed too high potential gradients inside and outside the arrester to be avoided, especially during the transient conditions, a phenomenon which can cause damages to the arrester insulating system bringing it to a premature failure [1]. Hence, the knowledge of the electric field can be useful for diagnostic tests [2,3], in order to check the condition of the varistor or the existence of moisture or pollution on the insulation surface [4].

As far as installed surge arresters in operation concerns, the comparison of the obtained measurements to previous records is required, in order to detect possible variations of the electric field around the arrester. The measurement of the electric field around the arrester is a very challenging and complicated procedure, either in a laboratory or in operating conditions that require use of specialized equipment. In case that field measurements are not available, simulation calculations of the developed electric field around the tested arrester could replace the lack of real recorded data. The theoretical computation of the electric filed can be performed by using proper simulation software (PC Opera, Comsol, etc.), considering, simultaneously, various operating scenarios (e.g., surface pollution, broken sheds, changes of the geometrical characteristics or the materials, etc.) [1,4–7]. However, the design of the equipment in a simulation software is a very time consuming and complex process, which requires not only the software licenses purchase but also the professional familiarization of users with it.

In the current work an alternative method using artificial neural networks (ANNs) for the calculation of the electric field around medium voltage metal oxide surge arresters is presented. ANNs have provided many solutions to power systems problems such as: load forecasting [8,9], wind and photovoltaic power systems

* Corresponding author. Tel.: +30 210 2896955.
E-mail address: vasvita@aspete.gr (V. Vita).

http://dx.doi.org/10.1016/j.epsr.2015.11.041
0378-7796/

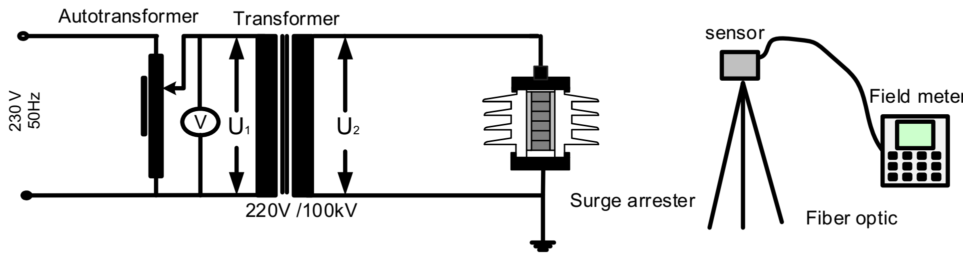

Fig. 1. Experimental set-up for the measurement of the electric field around the arrester.

control [10], distributed generation islanding detection [11], grounding systems [12] and lightning performance evaluation of high voltage transmission lines [13], due to their impressive computational speed, ability to handle complex non-linear functions, robustness and great efficiency, even in cases where full information for the studied problem is absent. The developed ANN model could be used by electric utilities, manufactures and laboratories, which either do not possess suitable measuring equipment or sophisticated simulation software, or want to compare their own measurements.

2. Experimental set-up

Surge arresters are connected in parallel with the equipment to be protected and they behave as insulators for the nominal operating voltage of the system and as conductors in case of overvoltages. Significant factors for the appropriate operation of the arrester are the installation position and the grounding resistance values. The basic electrical characteristics of the arresters are [14]: the maximum continuous operating voltage (MCOV): $U_c = (1.05–1.1)\,U$, where U is the rms value of the nominal voltage of the system, the rated voltage: $U_r = 1.25\,U_c$, the residual voltage (U_{res}): the voltage drop between the arrester's terminals when injecting an impulse current and the rated discharge current (for distribution arresters the nominal discharge current can be taken as a direct measure of the energy absorption capability). Basic parts of a medium voltage ZnO surge arrester are the electrodes, the insulation, the varistor discs and the fiber glass (between varistor and insulation) [15,16].

Fig. 1 presents the experimental set-up for the measurement of the electric field around a medium voltage surge arrester, by using two appropriate calibrated field meters (NARDA and PMM 8053). The use of two different field meters aimed to confirm the rightness of the experimental records and to show that the quality of the measurement results is strongly related to the used instrument [17,18]. Each field meter was connected with a sensor (EFA 300 and EHP-50B respectively) that was moved in different directions on the horizontal plane, in various distances along five different axes (considering the shape and the symmetry of the arrester), and in various heights. Fig. 2 presents the topology of the measurement axes.

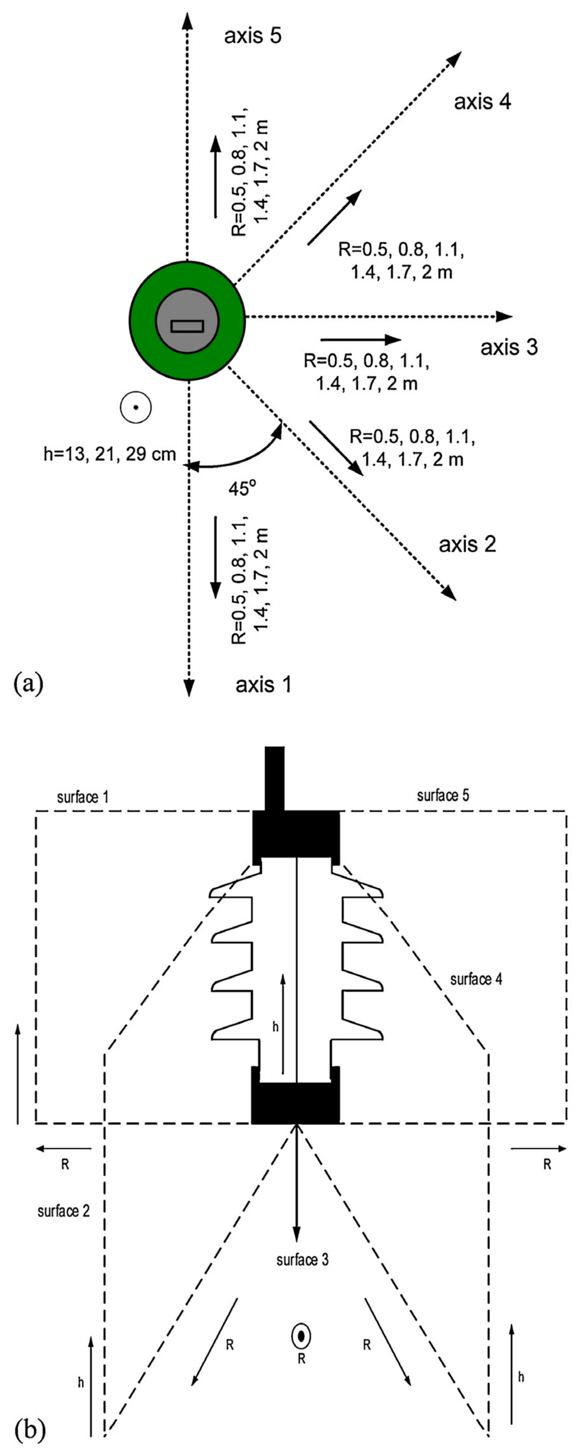

Fig. 2. Topology of the measurement axes ((a) floor plan, (b) 3d representation).

3. Simulation results

The electric field around metal oxide medium voltage surge arrester are computed by using the 2D and 3D version of PC Opera simulation software, a finite element analysis software for two and three dimensional electromagnetic design [19,20]. Disadvantage of the 2D simulation is that ignores the geometrical asymmetries, which may influence the results; on the other hand 3D simulations require a more detailed design and a longer simulation time.

Fig. 3(a) and (b) presents the designed surge arrester model and the obtained results for the electric field, by performing 2D