CHAPTER I

Introduction

1.1 General

The charge simulation method (CSM) is a well known boundary based method; commonly used for electric field analysis in high voltage engineering [1]. It is an appropriate and widely used numerical method for open boundary problems [2]. The method in its simplest form computes the simulation charge magnitudes by satisfying the boundary conditions at a selected number of contour points. The locations of the charges and the boundary conditions are predetermined and supplied based on the experience of the researcher.

Generally, the accuracy of the simulation results strongly depends on the type and number of charges, locations of charges and contour points and complexity of the electrode geometry [1, 2]. As such, the CSM programs for a particular application become case specific and depend on the programmer or developer personal experience. To set up an accurate CSM model, familiarity and understanding of the user with the CSM plays a key role. To assist the user and reduce the time required , empirical formula relating the locations of charges with those of the contour points were suggested and used [1]. One such widely used parameter is the assignment factor 'f_a' [1, 3]. Several optimization techniques have been suggested and utilized in order to reduce dependence on the individual experience and judgment usually required by the user using optimized CSM instead of using assignment factor 'f_a' as a guide parameter [4-9]. Such efforts, [10-13], evolve the optimal charge and contour point arrangement subject to a given objective function without relying on user the experience at the expense of highly increased computational burdens.

In the CSM, being a semi analytical technique, the shape of the geometry and symmetry (if any) play a major role [9]. Symmetry considerations reduce the degree of freedom in optimization so the search space is reduced and consequently the computational efforts are also reduced. Hence, the effort here is, to carry out a systematic study and evolve general guidelines to help set up accurate models. The search space is restricted by user planned models and the effort here is to see the effect of increased degrees of freedom on simulation accuracy of the models.

Using GA as an optimization tool [23-30], with the number of charges pre-decided, automatic allocation of these charges and contour points has been attempted relatively recently [10-13]. However, these efforts were rather limited to a narrow level of the non-uniformity of the geometry, use of simple geometry and/or a high computational burden. The present work is an effort to further investigate these limitations while devising procedures and techniques to overcome some of them for both simple and complex geometries.

1.2 Objective of the present work

The purpose of this work is to present efforts towards the automatic allocation, optimally, of the simulating charges as well as their values in the charge simulation method (CSM); thus reducing the dependence on the personal judgment and experience of the user. Using the basic type of simulating charges (point charges), the present work utilizes Genetic Algorithms (GA) as the optimization technique. An electrode system consisting of a sphere above a ground plane in 3-D spherical coordinate system is used in the study. Procedures are devised in order to determine appropriate arrangement, the radial and angular coordinates, of the fictitious simulating charges to achieve a minimum rms error in the potential values on the sphere surface for a wide range of non-uniformity factors of the geometry.

An alternate meshless numerical technique, recently used in various engineering applications, is the Method of Fundamental Solution (MFS) [31-39]. The method, which is the equivalent of the charge simulation when point charges are employed, is introduced in the present work. It is used, here, for the numerical computations of the charges, fields and forces in the geometry of a spherical particle between two parallel plates. Choosing appropriate locations of source points is crucial in the MFS as it has a great impact on the quality of the solution. Genetic algorithm (GA) is employed for the determination of optimal source points positions and values [40, 41]. Comparison of the results of both analytical and numerical techniques, which describe the acquired charge of the spherical particle, maximum electric field and electrostatic force exerted on the particle as well as other parameters of significance, are also carried out and presented to assess the effectiveness of the proposed procedures.

1.3 Contents of thesis

The thesis is presented in six chapters and one Appendix

Chapter I: presents an introduction to the thesis.

Chapter II: provides a description of concepts for the most popular numerical techniques for electric field calculations; namely the finite difference method (FDM), the finite element method (FEM), the boundary element method (BEM) and the charge simulation method (CSM). As well, this chapter provides a description of the components of genetic algorithms (GAs) as employed in the present work. A literature review of the recent publications is also presented.

Chapter III: presents the application of the charge simulation method (CSM) for the simulation of the geometry of sphere-plane gaps using a numbers of point charges along with genetic algorithms (GAs) to find the optimal locations and magnitudes of these charges for a wide range of non-uniformity factors. Detailed assessment of the accuracy aspects for the different arrangements of the simulating charges is carried out and presented. Procedures are devised for cases of very low non-uniformity factors.

Chapter IV: includes an introduction to the method of fundamental solution (MFS), its recent applications and the implementation of the method model the geometry of a spherical particle between two parallel plates when the sphere is in contact with the ground plate. Assessment and comparison of the accuracy aspects of the procedures is carried out for different particle radii and when other types of charges in the charge simulation are used.

Chapter V: details the different aspects regarding the application of the method of fundamental solution (MFS) for computing the electric charge, the electric force exerted on it and the electric field distributions for the same geometry of a spherical particle between two parallel plates. Assessment and comparison of the accuracy aspects of the procedures with available analytical formula is carried out and presented when the spherical particle takes different locations between the two parallel plates.

Chapter VI: presents conclusions and future work.