Multi-Weight-Function Indirect Boundary Element Method for Designing Shielding Cover for HVDC Converter System

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Abstract — In this paper, the study on Collocation and Galerkin approaches are carried out, which have their own advantages and disadvantages. A new method, called multi-weight-function indirect boundary element method (MWFIBEM) is proposed. In this method, the Collocation and Galerkin procedures were synthetically employed to deal with the continuous integral equations. It makes full use of the advantages of the two procedures and provides a better trade-off between accuracy and efficiency. The availability of this method is demonstrated by comparing the calculated results obtained by MWFIBEM with that obtained by finite element method (FEM).

I. Introduction

For some typical and idealized cases, analytical solutions for surface electric filed are available. However, for most practical problems involving electrical equipments with large-size and complex-structure, numerical methods have to be employed. The boundary element method has emerged as an effective numerical technique for electro-magnetic analysis and other computational engineering. It can be regarded as an important part of modern scientific computing. In BEM method, only the boundary of the domain is discretized, and the number of variables is determined only on the boundaries. Compared to domain-type methods such as finite element method (FEM) and finite difference method (FDM), this boundary method can decrease the problem size and the problem setup on a large scale.

In general, there are two basic procedures which are employed to deal with the continuous integral equation [1]-[2]. One is Collocation, and the other is Galerkin. The former is simple, convenient and time saving. In this procedure, the boundary integral equations are explicitly enforced at a finite set of points. In contrast to Collocation, the latter is more accurate and complicated [3]-[5]. In the Galerkin approach, the integral equations have not to be satisfied at any point. Instead the equations are enforced in a weighted average sense. Because it is obtained by projecting the exact solution onto the subspace consisting of all functions which are a linear combination of the shape functions, the Galerkin solution is therefore the linear combination that is the 'closes' to the exact solution. In addition, the treatment of hypersingular integrals with Galerkin approach is actually much simpler than with Collocation. The weighted averaging formula in the Galerkin BEM provides a reliable solution in the neighborhood of geometric discontinuities such as corners and junctions. However, the Galerkin approach involves one more integration compared to Collocation and has to take much more time to calculate the coefficients as shown in Fig. 1.

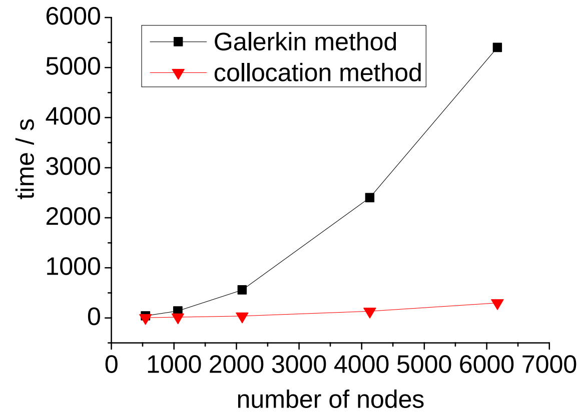

Fig. 1. Computing time comparison between Galerkin and Collocation method

In this paper, we combined the Collocation and Galerkin approaches in IBEM. Towards different field domains, different weight-functions are employed to reduce the continuous integral equation. When analyzing the critical areas where the field intensity is high, we adopt Galerkin procedure to discretize the integral equation. Otherwise, if the field intensity is low in some areas, Collocation will be implemented. This MWFIBEM that provides a better trade-off between accuracy and efficiency, proves simple and satisfactory.

II. Multi-Weight-Function IBEM

The main sources of error in discretizing the continuous equations are the three factors: the interpolation of the boundary, the interpolation of the boundary functions and the choice of weight-function. We take one of the most convenient schemes to accomplish the interpolation of the boundary and boundary functions. The boundary and boundary functions are represented through the same set of simple shape functions defined on a parameter space. The boundary surface S is approximated as a sum of small surface patches called elements, each of which is defined as a mapping from a fixed parameter domain in R^2. In this paper, we choose the 3D linear quadrilateral as shown in Fig. 2. The parametric variables will be called $\{\xi, \eta\}$, and the quadrilateral with vertices $h_1 = (-1, -1)$, $h_2 = (1, -1)$, $h_3 = (1,1)$, $h_4 = (-1,1)$ is defined by $-1 \leqslant \xi \leqslant 1$, $-1 \leqslant \eta \leqslant 1$.

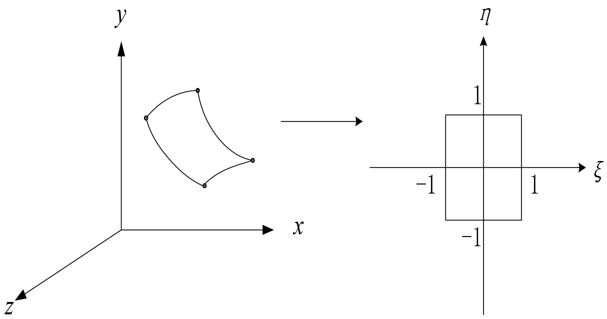

Fig. 2. The quadrilateral parameter space {ξ, η}

The function interpolations can be constructed based upon the linear shape functions

$$\begin{cases} N_1(\xi,\eta)=(1-\xi)(1-\eta)/4 \\ N_2(\xi,\eta)=(1+\xi)(1-\eta)/4 \\ N_3(\xi,\eta)=(1+\xi)(1+\eta)/4 \\ N_4(\xi,\eta)=(1-\xi)(1+\eta)/4 \end{cases} \quad (1)$$

After completing the interpolation of the boundary and boundary functions, we now discuss how to choose the weight-function according to the practical engineering problems. Take the shielding covers in HVDC converter system for example (see Fig. 3.), it can be obviously figured out that the maximum surface electric field exists on the corners on the basis of experience or electromagnetic theories. Consequently, much more attention should be paid to those areas during analyzing the field distribution while others can be attached little importance to.

Fig. 3. The shielding covers for HVDC converter system

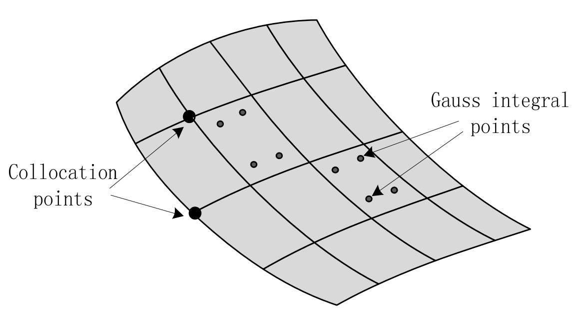

Fig. 4. The Collocation points and integration

As a result, we take two procedures: Collocation and Galerkin to deal with the integral equation. In the Galerkin approach, interpolation functions are taken as weight-function. In Collocation procedure, the nodes used to discretize the boundary are chosen to be Collocation points in order to avoid singular integrals (Fig. 4.).

III. APPLICATION AND VERIFICATION

To verify the principle described above, the surface electric field on shielding covers in ±800kV HVDC converter systems (Fig. 3.) was calculated by the MWFIBEM and FEM, respectively. The maximum field intensity can be seen from Fig. 5. and Fig. 6. They are 20.2 kV/ cm and 21.6 kV/ cm. The computational costs are shown in Tab. 1.

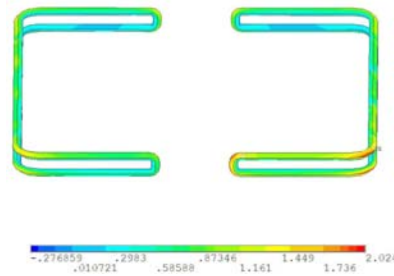

Fig. 5. The maximum field intensity obtained by the MWFIBEM

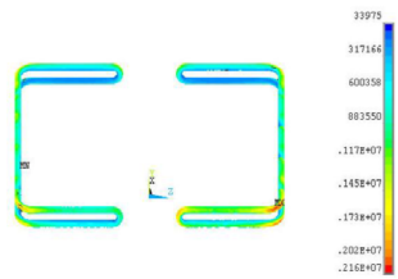

Fig. 6. The maximum field intensity obtained by FEM

TABLE I
COMPUTATIONAL COSTS COMPARISON BETWEEN THE FEM AND MWFIBEM

Item	FEM	MWFIBEM
Computer type	Server	Personal computer
Memory	20G	1.5G
Storage space	15G	300M
Time	2 hours	5 hours

IV. REFERENCES

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