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SOLUTIONS OF ELECTRIC-FIELD INTEGRAL EQUATION AND MAGNETIC-FIELD INTEGRAL EQUATION BY USING NUMERICAL ELECTROMAGNETIC CODE

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Abstract- Lots of places are affected by over voltages. Normally by using different conductors we can protect the towers and chimneys. But for this first we need to analyse the electric and magnetic field producing at the time of overvoltage. This will make easy to develop proper conductors or antennas for the proper protection of towers and chimneys. NEC-2 code, a standard tool for numerical analysis on electromagnetic field around antennasand the scatterers in the frequency domain., can be applied to analysis of lightning transient over voltages.It also solves integral equations at the boundary using the method of moments (MoM). The code solves three-dimensional boundary problems by using the electric-field integral equation. Project includes the basic theory of Electric field and Magnetic field integral equations and its solutions by using NEC-2, and explains how to tune the original program to fit for time-domain analyses. Then the set up of the input data for a simple test case is described. The accuracy of the analysis is demonstrated by comparison with an experiment, and finally, results of advanced study are presented.It can also be employed to determine the lightning surge response of tower and also to study the lightning interaction with the elevated strike objects.

Keywords:- Conductor, Current, Electromagnetic, Field Integral Equation, Lightning

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INTRODUCTION

The art of the electrical engineering design partly relies on the ability to properly model the physical structure under consideration. A good model enables an efficient and accurate analysis, so that the designer can reach his/her goal with a few iterations on the model and, usually, a few steps of experimental verification.

Electromagnetic field models are predominantly used by antenna and microwave engineers. The analysis starts from the physical structure (i.e., the geometry and electrical properties of materials involved), and it gives a full insight into the properties of devices and circuits (including propagation, radiation, parasitic effects, etc.). Most electromagnetic field problems [1] do not have an analytical solution and a numerical approach is required. However, writing a computer code for the solution of a class of problems is a hard task. Even to properly use codes for the electromagnetic field analysis, a lot of background and experience is required. This software is usually very sophisticated, it covers only a narrow region of applications, and it may sometimes require a long central processor unit (CPU) time to produce results. An efficient and accurate computer simulation of various electromagnetic field problems, including antennas, is made possible by modern fast computers and well-developed numerical techniques. This simulation enables an antenna designer to visualize the targeted antenna on the desktop, providing in many cases more information than can ever be measured in the laboratory or in situ, at a lower cost and higher efficiency. A good personal computer and appropriate software may cost significantly less than antenna measurement instrumentation required to equip an antenna laboratory.

The software used for the frequency domain analysis is NEC (Numerical Electromagnetic Code)[7]. NEC-2 is a computer code used to analyze 3D electromagnetic field around the antenna and the scatterers in the frequency domain. It also solves integral equations at the boundary using the method of moments (MoM). It can also be employed to determine the lightning surge response of tower and also to study the lightning interaction with the elevated strike objects.

There exists a variety of numerical methods for the analysis of electromagnetic fields. They are based on the solution of Maxwell's equations or certain equations derived from them. Maxwell's equations are fundamental equations for electromagnetic fields and they can be in integral or differential form. The numerical methods for field analysis can be classified in a variety of ways. Most numerical techniques deal with linear systems, as are most antenna structures. Such systems can always be described in terms of linear operator equations. An operator is a mapping of a function space to a function space. Hence, the unknown in an operator equation is a function. Some techniques deal with nonlinear systems, but they are not within our scope here.

II.PRELIMINARY STUDIES

1. Lightning Transient Impulse Voltage[2][3]

At any given time there are about 1800 thunderstorms in progress around the world, with lightning striking about 100 times each second. In the U. S., lightning kills about 150 people each year and injures another 250. In flat terrain with an average lightning frequency, each 300 foot structure will be hit, on average, once per year. Each 1200 foot structure, such as a radio or TV tower, will be hit 20 times each year, with strikes typically generating 600 million volts. Each cloud-to-ground lightning flash really contains from three to five distinct strokes occurring at 60 millisecond intervals, with a peak current of some 20,000 Amperes for the first stroke and about half that for subsequent strokes. The final stroke may be followed by a continuing current of around 150 Amps lasting for 100 milliseconds.

The rise time of these strokes has been measured to be around 200 nanoseconds or faster. It is easy to see that the combination of 20,000 Amps and 200 nanoseconds calculates to a value, dI/dt, of 1011Amps per second! This large value means that transient protection circuits must use radio frequency (RF) design techniques, particularly considerate of parasitic inductance and the capacitance of the conductors. While this peak energy is certainly impressive, it is really the longer term continuing current which carries the bulk of the charge transferred between the cloud and ground.

Electrical transients in the form of voltage surges have always existed in electrical distribution systems, and prior to the implementation of semiconductor devices, they were of minor concern.All electrical and electronic devices can be damaged by voltage transients.

Like lightning there are a lot of chances for occurring over voltages and also along with this electric and magnetic field will occur.Actually the name “Electric field integral equation and Magnetic field integral equation” doesn’t convey a meaning that these are a set of equation or anything like numerical things. But this also includes numerical parameters.

B.Field Integral Equation

The electric-field integral equation is a relationship that allows the calculation of an electric field intensity (E) generated by an electric current distribution(J).

Field Integral equations can be solved with current distribution to analyse the radiation pattern around the particular conductor.

Computational electromagnetic, computational electrodynamics or electromagnetic modelling is the process of modelling the interaction of electromagnetic fields with physical objects and the environment.

It typically involves using computationally efficient approximations to Maxwell's equations and is used to calculate antenna performance, electromagnetic compatibility, radar cross section and electromagnetic wave propagation when not in free space.

A specific part of computational electromagnetics deals with electromagnetic radiation scattered and absorbed by small particles

C.Maxwell’s Equation

All the parameters we are using in this field analysis derived and explains with the help of Maxwell’s equation[5]. A sinusoidal plane wave is one special solution of these equations. Maxwell's equations explain how these waves can physically propagate through space. The changing magnetic field creates a changing electric field through Faraday's law.

Maxwell's equations are a set of partial differential equations that, together with the Lorentz force law, form the foundation of classical electrodynamics, classical optics, and electric circuits. These fields in turn underlie modern electrical and communications technologies. Maxwell's equations describe how electric and magnetic fields are generated and altered by each other and by charges and currents. They are named after the physicist and mathematician James Clerk Maxwell, who published an early form of those equations between 1861 and 1862.Theequations have two major variants. The "microscopic" set of Maxwell's equations uses total charge and total current, including the complicated charges and currents in materials at the atomic scale; it has universal applicability but may be infeasible to calculate. The "macroscopic" set of Maxwell's equations defines two new auxiliary fields that describe large-scale behaviour without having to consider these atomic scale details, but it requires the use of parameters characterizing the electromagnetic properties of the relevant materials.

D.Electromagnetic Field Analysis

More number of methods are available for analysing electromagnetic field numerically. Few of them are,

•Method of Moments (MoM)[6]
•Finite Element Method (FEM)
•Finite difference time-domain (FDTD) method
•Thin-Wire Time-Domain (TWTD) code

NEC is using MoM and this is calculating only boundary values, rather than values throughout the space, it is significantly more efficient in terms of computational resources for problems with a small surface/volume ratio.

III.WORKING PROCEDUDRE

Collected set of oscilloscope signals and done the analysis with the help of Matlab.In this stage created FFT.Plotted the graph for frequency spectrum as well as both interpolation for the detailed analysis.

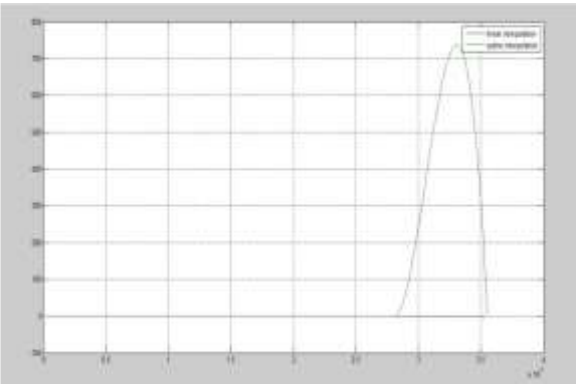


Fig 1. Linear and Spline Interpolation

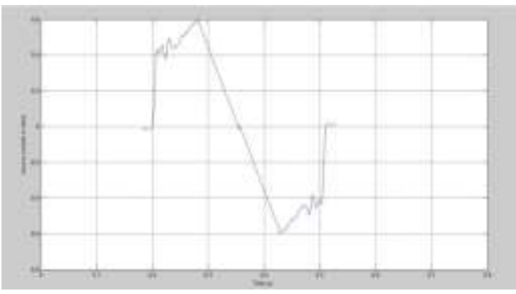


Fig 2. Source Current Vs Time

Then the same samples analysed for various timeand delays. Time taken as 3*10-6 s and 5*10-6s and the delay taken as 0.5*10-6 s and 1*10-6 s.

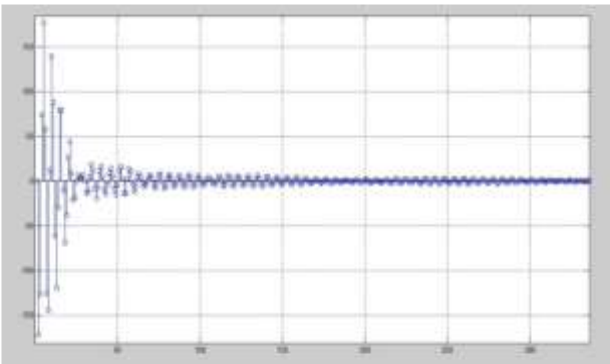
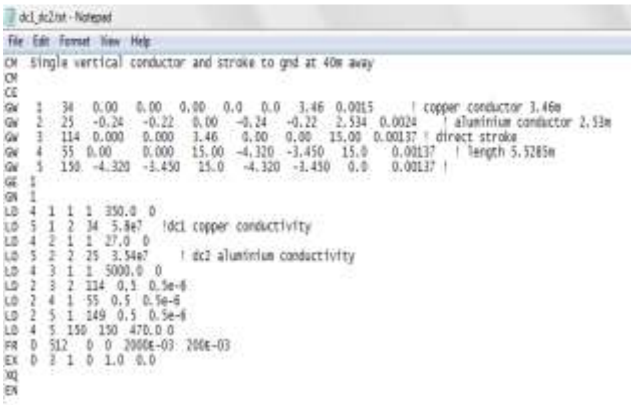


Fig 3. Spectrum for the time 3*10-6 s and the delay 0.5*10-6 s

Here observed that while delay increase frequencies come more closer and same as this increasing time will make frequencies come closer.
Separate folder created in computer for keeping all NEC files and Matlab files together.
Matlab code created for Read function and in which only the Cartesian form will be read. Current data of any number of output segments will be read. It will automatically read till the end of file, variables 'tf_freq' & 'tranfu' holds the frequency and transfer functions respectivelyand 'out_file' is the output file of NEC2D. Then the Matlab code for Get function created.The value of the transfer functions for the input frequency, values outside the range will be set to the respective limits, variable 'var' holds the variable number in the 'transfu' and 'tri' is the result in Cartesian form in the code.
Also created a code in Matlab for analysing impulse ie; to make CTF and to plot the same. Then next is creation of NEC file and the output of that NEC is called by Matlab for getting CTF. For each and every segment it will plot CTF and from that analysis will be easy.



```
dc1_dc2.txt - Notepad
File Edit Format View Help
CM  Single vertical conductor and stroke to gnd at 40m away
CM
CE
GW  1  34   0.00   0.00   0.00   0.0    0.0    3.46   0.0015     ! copper conductor 3.46m
GW  2  25   -0.24  -0.22  0.00   -0.24  -0.22  2.534  0.0024     ! aluminium conductor 2.53m
GW  3  114  0.000  0.000  3.46   0.00   0.00   15.00  0.00137 ! direct stroke
GW  4  55   0.00   0.000  15.00  -4.320 -3.450 15.0   0.00137  ! length 5.5285m
GW  5  150  -4.320 -3.450 15.0   -4.320 -3.450 0.0    0.00137 !
GE  1
GN  1
LD  4  1  1  1  350.0  0
LD  5  1  2  34  5.8e7   !dc1 copper conductivity
LD  4  2  1  1  27.0  0
LD  5  2  2  25  3.54e7    ! dc2 aluminium conductivity
LD  4  3  1  1  5000.0  0
LD  2  3  2  114  0.5  0.5e-6
LD  2  4  1  55  0.5  0.5e-6
LD  2  5  1  149  0.5  0.5e-6
LD  4  5  150  150  470.0 0
FR  0  512  0  0  2000E-03  200E-03
EX  0  3  1  0  1.0  0.0
XQ
EN
```

Fig 4. NEC code which is used for analysing impulse

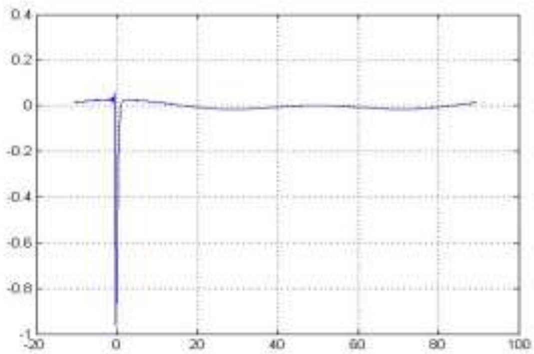
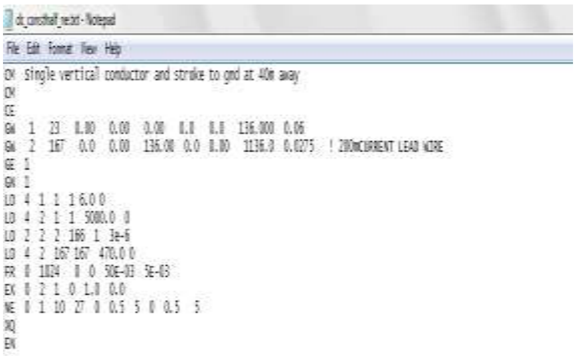


Fig 5. CTF of one segment

Then the NEC codes created for two separate cases like conductor radius constant and channel radius halved and conductor radius constant and channel radius doubled.



```
CM Single vertical conductor and stroke to gnd at 40m away
CM
CE
GW 1 23 0.00 0.00 0.00 0.0 0.0 136.000 0.06
GW 2 167 0.0 0.00 136.00 0.0 0.00 1136.0 0.0275 ! 200mCURRENT LEAD WIRE
GE 1
GN 1
LD 4 1 1 1 6.0 0
LD 4 2 1 1 5000.0 0
LD 2 2 2 166 1 3e-6
LD 4 2 167 167 470.0 0
FR 0 1024 0 0 50E-03 5E-03
EX 0 2 1 0 1.0 0.0
NE 0 1 10 27 0 0.5 5 0 0.5 5
XQ
EN
```

Fig 6. NEC Code of conductor radius constant and channel radius halved

Figure 5 showing the NEC code of conductor radius constant and channel radius halved and at the time of doubling the channel radius giving the value 0.12 and 0.055 instead of 0.06 and 0.0275.

Then analyzed each segment as like previous but for the situation of channel radius halved and doubled.The program gave 6 different graphs.First one is impulse wave form and other 5 graphs are for each segment.Graph gives the base and peak values of x-axis, y-axis, Del(x), time and velocity.

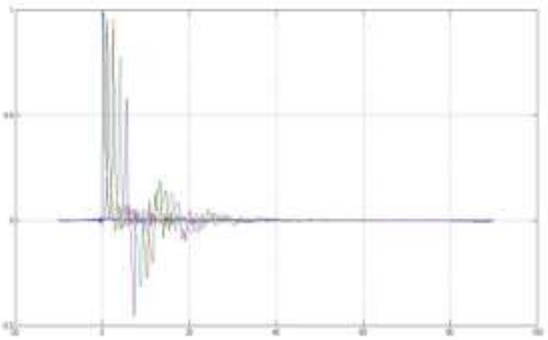


Fig 7. CTF of one segment when channel radius halved

IV.CONCLUSION

The objective of the project was to be analyse the electrical and magnetic field, occurring at the time of over voltage for protecting tall structures and chimneys.

The different methods for the solution of electric field integral and magnetic field integral equation were studied. The optimum method to be employed was found to be method of moments (MoM).The fast fourier transform of the equivalent signals were computed using Matlab. NEC codes created for different conditions. At the time of channel radius halved and doubled was analysed by plotting CTF using Matlab.

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