The International Journal of Engineering and Information Technology

journal homepage:www.ijeit.misuratau.edu.ly

MISURATA UNIVERSITY

Evaluating the Electromagnetic Field Problem Generated by the Power Transmission Line Using High Order Compact Method

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Abstract— **This paper compares a finite difference method-based computational scheme for evaluating electromagnetic field problems in power transmission lines in cases of on surface and in Ground. The scheme uses Maxwell's partial differential equations to represent electric and magnetic field components and approximate boundary conditions. The High Order Compact Method (HOC) is applied to estimate the electric field (E_z)in ground and compares it with the standard central difference scheme. The HOC produces more accurate results than the traditional central approximation at 99.7% for the electric field E_z. It also calculates both of Electric and magnetic intensity to evaluate the effect of Electric and magnetic intensities in ground and on surface respect to distance.**

Index Terms— **Power Transmission Line- Central Difference Scheme - High Order Compact, Boundary conditions, Electric intensity, magnetic intensity**

List of Principal Symbols

HOC *High Order Compact Method*
Ez *Electric field in the z-direction*
Ex *Electric field in the x-direction*
Ey *Electric field in the y-direction*
Hxg *Magnetic field in the x-direction in the ground*
Hyg *Magnetic field in the y-direction in the ground*
Hxi *image components of Magnetic field in the x-direction on surface*
Hyi *image components of Magnetic field in the y-direction on surface*
Ω *Angular frequency*
kV *Kilovolts*
μ_0 *Permeability of free space*
ε_0 *Permittivity of free space*
ρe *Electrical resistivity of the ground*
I *Current in the transmission line*
E *Complex valued vector of electric field.*
H *Complex valued vector of magnetic field.*
i *Vector of current density*
h *Height of the transmission line above ground*
δx *Grid spacing in the x-direction*
FDM *Finite Difference Method*
ELF *Extremely Low Frequency*
EMF *Electromagnetic Field*

Received 23 Apr , 2024; revised 08 May, 2024; accepted 15 Mar 2024.
AVAILABLE ONLINE 08 AUG, 2024.

I. INTRODUCTION

In recent studies, scientific systems have performed significant research investigating existing electromagnetic field issues through a high order compact method. The methods open up the possibility of reducing the computational error and getting an accurate representation of the electromagnetic fields nearby electrical transmission lines. Available sources confirm that the high-order compact method is an essential approach to the assessment of electromagnetic field issues due to the provision of results with high accuracy and the reduced computational requirements, to enhance the resolution at high wavenumbers, [1] [2]. Finite Difference Method has been applied to investigate electromagnetic fields within systems ranging from power transformers to generators. The work has been mainly focused on small-scale systems; as power transmission lines above the earth over long distances. As an introduction to the High Order Compact Difference Method, a computational technique that supports the assessment of electromagnetic fields made by currents flowing through the power transmission line, mainly single-phase-to-earth error conditions, the process was used to develop advanced protocols for numerically based on Carson’s formulation assumptions, the electric field components of electric field in the x-direction(Ex) and electric field in the y-direction(Ey) due to the ground current are neglected, and the only significant component is E_Z by Elhirbawy, M. A., et al., analyzing the electromagnetic field’s influence on power transmission lines. Also in 2002, [M. Elhirbawy et al. use the Finite Difference Method (FDM) for calculating electromagnetic fields in power transmission lines. FDM is simple to formulate and extends to two- or three-dimensional problems with less computational work. The study calculates magnetic and electric fields using various parameters like step size, conductor height, resistivity, and fault current. The study concludes that FDM is a valuable numerical technique for solving Maxwell's partial differential equations, offering a comprehensive approach to electromagnetic field problems. In 2003, Al Dhalaan, S. M. et al. showed there was a small change in the electromagnetic field magnitudes for frequencies of 50 and 60 Hz. In conclusion, the paper provides insights into magnetic coupling between power transmission lines and metallic structures like railways at surface level ,[4]. It offers a comprehensive analysis of electromagnetic field distribution near high-voltage low-frequency lines, serving as an alternative tool for such calculations.

The High Order Compact Difference Method shows great promise for the assessment of magnetic coupling at the supply frequency between transmission lines and metallic structures buried in the ground, such as pipelines. Various literature reviews and discussions within the power industry have highlighted the urgent requirement for critical means of addressing the many demanding electromagnetic field problems that arise from transmission lines.

II. BACKGROUND

A. High-Order Compact Methods: Advantages of using the high-order compact method for power transmission lines: Space-Efficiency: Compact transmission lines designed using this method take less lateral space, according to modern materials and altered tower geometries, reducing visual impact and space requirements.

Cost-Effectiveness: The construction of compact overhead lines is often cheaper than traditional lines, especially in the 20–220 kV voltage range, making it an economical and attractive solution, [2].

Reliability and Safety: The design of compact lines improves reliability, safety, and the transiting ability of power lines, ensuring improved performance and reduced risks associated with electromagnetic fields.

Increased Voltage Gradients: By reducing phase-to-phase and phase-to-structure distances, the high-order compact method increases voltage gradients on conductors, which will lead to reduced flashover voltage thresholds and improved performance, [2].

Environmental Performance: The reduction of electromagnetic fields in outer space through compact line design can lead to improved environmental performance of the power line, making it a more sustainable option.

A class of high-order compact (HOC) exponential finite difference (FD) algorithms is used to solve many problems, such as steady-state convection-diffusion problems, in one and two dimensions. The recently suggested HOC exponential FD schemes are appropriate for convection-dominated environments and produce highly accurate approximation solutions. The tridiagonal Thomas algorithm can be used to solve the diagonally dominant tri-diagonal system of equations that are produced by the $O(h^4)$ compact exponential FD schemes designed for one-dimensional (1D) problems. The line iterative approach with alternating direction implicit (ADI) procedure allows us to deal with diagonally dominant tridiagonal matrix equations, which can be solved by application of the one-dimensional tridiagonal Thomas algorithm. $O(h^4 + k^4)$ compact exponential FD schemes are formulated on the nine-point 2D stencil for the two-dimensional (2D) problems.[7]

When simulating a variety of physical processes, typical low-order algorithms can have restrictions that can be overcome by using high-order numerical approaches, such as electromagnetics, High-order approaches can yield more accurate results on finer computational grids than low-order techniques because of their improved capacity to represent waves at high frequencies and/or with limited grid support. This leads to a reduction in the overall computing effort. But most of the early attempts at employing high-order methods, simple domains, and Cartesian grids have been used for a number of reasons, including the lack of defined curvilinear-grid techniques for various types of high-order approaches and the limited flexibility of spectral methods, [8].

B. Power Transmission Line Models: Electric fields, measured in kV/m, are invisible forces between positive and negative charges in various locations, like home wiring and power lines. Their strength is directly proportional to system voltage, and electric take-off is safe, [5].

Electricity is produced, transported, and disseminated through power lines, cables, and electrical equipment, involving magnetic and electric fields. Electrical systems operate at 50 Hz and produce extremely low-frequency (ELF) EMF. Voltage determines electric fields, and surrounding a transmission line, the electric field remains relatively constant. Higher operating voltage leads to higher electric fields around the conductor, partially at ground level, [8]. The ICNIRP basic restriction and reference levels indicate that the electric field around the head is 0.02 v/m, while all tissues of the head and body are 0.4 v/m, [6]. The ground's surface connects the two regions, which are above and below ground. An effective boundary condition has been applied for a small diameter in the ground. These boundaries are the nine HOC points around the surface, as the region of the power transmission line is assumed to have been calculated for the electric and magnetic fields on the surface to be applied as a boundary condition,[4].

C. Boundary Points and Conditions: Boundary conditions for boundaries at a long distance, utilizing the Carson formulation, as shown in Fig. 1 which is determined from the conductors of both regions. The total magnetic field [3]. (the sum of the conductor and image contributions) must match the magnetic field below ground at the surface in order to satisfy the boundary criteria of continuity in both the horizontal and vertical components of magnetic fields at the ground surface, For the model fault current is 10000A and the conductor height is 18.5 meter, the supply frequency is 50 Hertz, consider the resistivity of the earth ground 100 Ω

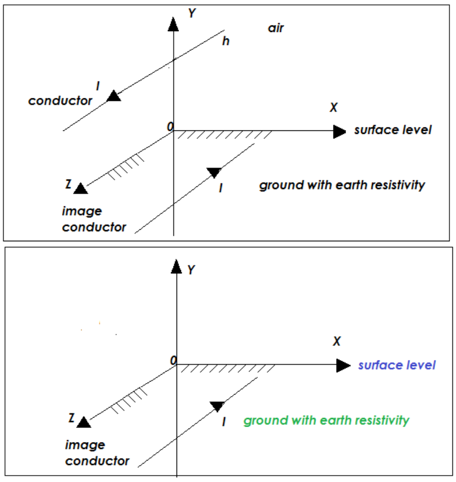

Figure 1. Carson formulation [1]

D. Magnetic Field on the Surface: Transmission and distribution lines for electricity have been in service for roughly seventy years. The electric exposed to magnetic fields from power wires and other sources may be experiencing health effects, [9]. So it has been implemented to calculate the image components H_{xi} and H_{yi}, [5].

E. Electric Field in the Ground: Using the Maxwell equations, [5]:

curl(E)= $-j\omega\mu_0 H$ (1)

curl(H)= i + $j\omega\varepsilon_0 E$ (2)

Electric filed related to current density (i)

i = E/ρ_e (3)

curl H= $E/\rho_e + j\omega\varepsilon_0 E$ (4)

when $\frac{1}{\rho_e} \gg \omega\varepsilon_0$, then curl H= E/ρ_e (5)

By tacking the curl of "(1)," in Carson's assumption for the electric field of x-direction ***(Ex)*** and the electric field of y-direction(***Ey)*** in the ground are negligible in comparison with the electric field of z-direction ***(Ez)*** .

Then crul (curl(E))=(0,0,$-\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2}$) (6)

So "(6)," is reduced to an equation for z-direction only, [5].

III. MODELING AND SIMULATION

III.1 IN GROUND FIELDS ASSESSMENT

A. Mathematical modeling: Calculate the exact solution for an electric field of z-direction E_z in the ground for equation, [5]:

$$E_z = -\int_0^\infty F(u)\cos(ux)e^{y\sqrt{u^2+j\alpha}}\,du \quad (7)$$

$$F(u) = \frac{\mu_0}{\pi}\frac{j\omega I e^{-hu}}{\sqrt{u^2+j\alpha}+u} \text{ and } \alpha = \mu_0\omega/\rho_e \quad (8)$$

B. The mathematical representation for in-ground field assessment is expressed. However, the solution for this expression to evaluate resultant field is bit tedious, so the choice to numerical solution.

To evaluate the solution directly The Numerical Solutions High – Order compact finite difference method has been chosen to suit the chosen model with uniform grids that is Δx= Δy= δx=1 .

High –Order compact finite difference method (nine points) :

20u(i,j)= 4(u (i-1,j)+ u (i+1,j)+ u(i,j-1)+ u (i,j+1))+ u(i-1,j-1)+u(i+1,j+1)+u(i-1,j+1)+ u(i+1,j-1) (9)

let Δx =1/4 , where i =1,2,3 and j=1,2,3.

C. Mathematical representation for central finite Difference Method:

2u(i,j)=u(i+1,j)+u(i-1,j)+u(i,j+1)+u(i,j-1) (10)

For comparison with the above HOC method, the FDM is also considered

D. Results and Discussion: Calculate the exact solution for an electric field of z-direction in the ground E_z ,[5]. As shown in Fig. 2

$$E_z = -\int_0^\infty F(u)\cos(ux)e^{y\sqrt{u^2+j\alpha}}\,du \quad (11)$$

$$F(u) = \frac{\mu_0}{\pi}\frac{j\omega I e^{-hu}}{\sqrt{u^2+j\alpha}+u} \quad (12)$$

where $\alpha = \mu_0\omega/\rho_e$

E_z = -0.48254386 + -2.50786568i

E. Numerical Solutions: Central Finite Difference Method for "(6)," shown in Table I:

2u(i,j)=u(i+1,j)+u(i-1,j)+u(i,j+1)+u(i,j-1)

let Δx =1/4 , where i=1,2,3 and j=1,2,3

TABLE I. CENTRAL DIFFERENCE SOLUTION

0.23986235573 + 1.33660702431i	0.72433638946 + 3.73416188467 i	0.24403602309 + 1.1174479979 i
0.72102144552 + 3.92041908094 i	1.44676683742 + 7.56071073234 i	0.72602964688 + 3.6220954613i
0.23849900118 + 1.41326460710 i	0.72214619297 + 3.84474503768 i	0.24211582234 + 1.1889084026 i

From Table I, error1 is -0.7224 - 3.8445i

F. High –Order compact finite difference method in "(9)," (nine points):

20u(i,j)= 4(u(i-1,j)+ u(i+1,j)+ u(i,j-1)+ u(i,j+1))+ u(i-1,j-1)+u(i+1,j+1)+ u(i-1,j+1)+ u(i+1,j-1)

let Δx =1/4 , where i=1,2,3 and j=1,2,3 shown in Table II:

TABLE II. HIGH –ORDER COMPACT SOLUTION

-0.4826035176 - 2.5046011660i	-0.48208321336 - 2.54024889550i	-0.48150017286 - 2.58110252260i
-0.482698884 - 2.496846413 i	-0.482242450112 -2.528594563154i	-0.48163434556 - 2.56997302187 i
-0.4828602098 - 2.4850418245 i	-0.48255991185 - 2.50703379709i	-0.4819796792 -2.5447372389 i

From Table II , error2 is 0.0001 - 0.0033i , so Figure 2 showed Comparing between the exact solution, with central difference solution and HOC solution.

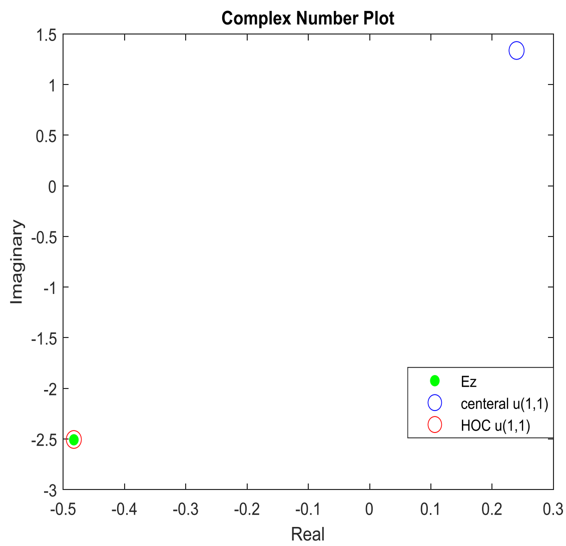

Figure 2. Comparing between the exact solution E_z = -0.48254386 + -2.50786568i with central difference solution 0.23986235573 + 1.33660702431i and HOC solution -0.4826035176 - 2.5046011660i

G. Magnetic field in the ground in Figure 3, the exact solution for hx_g and hy_g, [5]. Let Hgx=h & Hyg= H

$$H_{xg} = \int_0^\infty F(u)\cos(ux)e^{y\sqrt{u^2+j\alpha}}\frac{\sqrt{u^2+j\alpha}}{j\omega\mu_0}du \quad (13)$$

$$H_{yg} = \int_0^\infty F(u)\sin(ux)e^{y\sqrt{u^2+j\alpha}}\frac{1}{j\omega\mu_0}du \quad (14)$$

"Equation (12) is $F(u) = \frac{\mu_0}{\pi}\frac{j\omega I e^{-hu}}{\sqrt{u^2+j\alpha+u}}$ "

Where $\alpha = \mu_0\omega/\rho_e$,Δx=Δy= 1 = δx

$E_z(i,k)$ =2 $\delta x/\rho_e = M_{(i,k)}$ i=1,2 and K=1,2

hx_g 92.12159282193053 + 1.3890352006998854i

hy_g 89.37980389978173 − 1.3639880636854207i

Central Difference method for h_{xg} and h_{yg} system equation are:

$$h_{(i+1,k)} - h_{(i-1,k)} + H_{(i,k+1)} - H_{(i,k-1)} = 0 + i0 \quad (15)$$

$$H_{(i+1,k)} - H_{(i-1,k)} - h_{(i,k+1)} + h_{(i,k-1)} = M_{(i,k)} \quad (16)$$

At : i=1 , k=1

$$h_{(2,1)} - h_{(0,1)} + H_{(1,2)} - H_{(1,0)} = 0 \quad (17)$$

$$H_{(2,1)} - H_{(0,1)} - h_{(1,2)} + h_{(1,0)} = M_{(1,1)} \quad (18)$$

At : i=2 , k=1

$$h_{(3,1)} - h_{(1,1)} + H_{(2,2)} - H_{(2,0)} = 0 \quad (19)$$

$$H_{(3,1)} - H_{(1,1)} - h_{(2,2)} + h_{(2,0)} = M_{(2,1)} \quad (20)$$

At : i=1 , k=2

$$h_{(2,2)} - h_{(0,2)} + H_{(1,3)} - H_{(1,1)} = 0 \quad (21)$$

$$H_{(2,2)} - H_{(0,2)} - h_{(1,3)} + h_{(1,1)} = M_{(1,2)} \quad (22)$$

At : i=2 , k=2

$$h_{(3,2)} - h_{(1,2)} + H_{(2,3)} - H_{(2,1)} = 0 \quad (23)$$

$$H_{(3,2)} - H_{(1,2)} - h_{(2,3)} + h_{(2,1)} = M_{(2,2)} \quad (24)$$

Rearrange the equations:

From (22) $h_{(1,1)} + H_{(2,2)} = M_{(1,2)} + H_{(0,2)} + h_{(1,3)}$ (25)

From (17) $h_{(2,1)} + H_{(1,2)} = h_{(0,1)} + H_{(1,0)}$ (26)

From (18) $h_{(1,2)} - H_{(2,1)} = -M_{(1,1)} - H_{(0,1)} + h_{(1,0)}$ (27)

From (20) $h_{(2,2)} + H_{(1,1)} = -M_{(2,1)} + H_{(3,1)} + h_{(2,0)}$ (28)

From (21) $-h_{(2,2)} + H_{(1,1)} = H_{(1,3)} - h_{(0,2)}$ (29)

From (23) $h_{(1,2)} + H_{(2,1)} = H_{(2,3)} + h_{(3,2)}$ (30)

From (24) $-h_{(2,1)} + H_{(1,2)} - M_{(2,2)} + H_{(3,2)} - h_{(2,3)}$ (31)

From (19) $-h_{(1,1)} + H_{(2,2)} = H_{(2,0)} - h_{(3,1)}$, Results in Fig. 3 For Central Difference Solution of Magnetic field in the x-direction in the ground (Hxg):

101.410334224241964 + 1.394122045424379i, Central Difference Solution of Magnetic field in the y- direction in the ground (Hy_g):

177.732152021410798 -2.7179992803359 90i

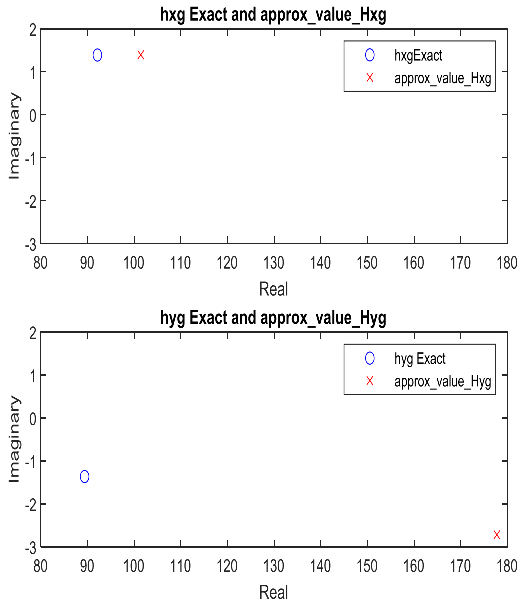

Figure 3. Comparing between Exact solution, Central Difference Solution Magnetic field (hxg & hyg) for above figure the absolute_Error1 (Hxg) is 9.2887 and the below figure absolute_error2(Hyg) is 88.3627

The equation: $-2H_{xi}(i,k) + H_{xi}(i, k+1) + H_{xi}(i+1, k) + H_{yi}(i,k+1) - H_{yi}(i+1,k) = 0+j0$ (32)

It come out from subtract both of:

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = 0 \quad (33)$$

and $\frac{\partial H_x}{\partial x} + \frac{\partial H_y}{\partial y} = 0$ (34)

Then using forward difference to approximate the derivative in first order. [5]

$$\frac{\partial f}{\partial x} = \frac{f_{i+1,k} - f_{i,k}}{\Delta x}\ , \frac{\partial f}{\partial y} = \frac{f_{i,k+1} - f_{i,k}}{\Delta y} \quad (35)$$

subtract "(26),"*from* "(27),":

$$\frac{\partial H_x}{\partial x} + \frac{\partial H_y}{\partial y} - \left(\frac{\partial H_y}{\partial x} + \frac{\partial H_x}{\partial y}\right) = 0 \quad (36)$$

$$\frac{\partial H_x}{\partial x} + \frac{\partial H_y}{\partial y} - \frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = 0 \quad (37)$$

$$\frac{\partial H_{xi}}{\partial x} + \frac{\partial H_{yi}}{\partial y} + \frac{\partial H_{xi}}{\partial y} - \frac{\partial H_{yi}}{\partial x} = 0 \quad (38)$$

Used forward difference

$$\frac{H_{xi(i,k+1)} - H_{xi(i,k)}}{\Delta y} + \frac{H_{xi(i+1,k)} - H_{xi(i,k)}}{\Delta x} + \frac{H_{yi(i,k+1)} - H_{yi(i,k)}}{\Delta y} - \left(\frac{H_{yi(i+1,k)} - H_{yi(i,k)}}{\Delta y}\right) = 0 \quad (39)$$

$\Delta x = \Delta y$ now re-arrange: the above "(39)." and using forward difference

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} + \frac{\partial H_x}{\partial x} - \frac{\partial H_y}{\partial y} = 0$$

(40)

`

$$\frac{\partial H_{yi}}{\partial x} + \frac{\partial H_{yi}}{\partial y} + \frac{\partial H_{xi}}{\partial x} - \frac{\partial H_{xi}}{\partial y} - = 0$$

(41)

used forward difference and $\Delta x = \Delta y$

$$\frac{H_{yi(i+1,k)} - H_{yi(i,k)}}{\Delta x} + \frac{H_{yi(i,k+1)} - H_{yi(i,k)}}{\Delta y}$$

$$+\frac{H_{xi(i+1,k)} - H_{xi(i,k)}}{\Delta x} - \left(\frac{H_{xi(i,k+1)} - H_{xi(i,k)}}{\Delta y}\right) = 0$$

Rearrange after making $\Delta x = \Delta y$ to get equation[5]

$-2H_{yi}(i,k) + H_{xi}(i+1, k) - H_{xi}(i, k+1) + H_{yi}(i+l,k) + H_{yi}(i,k+l) = 0+j0$ (42)

III.2 ON SURFACE FIELDS ASSESSMENT

H. Electric Field on Surface, [5].In Figure 6, From curl(E)= - $j\omega\mu_0 H$ using backward difference :

$$\frac{\partial f}{\partial y} = \frac{f_{i,k} - f_{i,k-1}}{\Delta y} \quad (43)$$

$$\frac{\partial E_z}{\partial y} = -j\omega\mu_0 H \quad (44)$$

$$\frac{E_{z(i,k)} - E_{z_{(i,k-1)}}}{\Delta y} = -j\omega\mu_0 H \quad (45)$$

$$\Delta x = \Delta y = \delta x$$

$$E_{z(i,k)} - E_{z_{(i,k-1)}} = -j\delta x\omega\mu_0 H_{xg(i,k)} \quad (46)$$

Then get the equation, [5].

$$E_{z(i,k)} + j\delta x\omega\mu_0 H_{xg(i,k)} - E_{z_{(i,k-1)}} = 0 \quad (47)$$

I. Magnetic Field on Surface in Figure 7

Let $H_{xi} = h$, $H_{yi} = H$, system has i=1,2 k= 1,2

From "(32)," :

$$-2h_{i,k} + h_{i,k+1} + h_{i+1,k} + H_{i,k+1} - H_{i+1,k} = 0 \quad (48)$$

At i=1 , k=1

$$-2h_{1,1} + h_{1,2} + h_{2,1} + H_{1,2} - H_{2,1} = 0 \quad (49)$$

At i=2 , k=1

$$-2h_{2,1} + h_{2,2} + h_{3,2} + H_{2,2} - H_{3,1} = 0 \quad (50)$$

At i=1 , k=2

$$-2h_{1,2} + h_{1,3} + h_{2,2} + H_{1,3} - H_{2,2} = 0 \quad (51)$$

At i=2 , k=2

$$-2h_{2,2} + h_{2,3} + h_{3,2} + H_{2,3} - H_{3,2} = 0 \quad (52)$$

From the following"(42),":

$$-2H_{i,k} + h_{i+1,k} - h_{i,k+1} + H_{i+1,k} + H_{i,k+1} = 0$$

At i=1 , k=1

$$-2H_{1,1} + h_{2,1} - h_{1,2} + H_{2,1} + H_{1,2} = 0 \quad (53)$$

At i=2 , k=1

$$-2H_{2,1} + h_{3,1} - h_{2,2} + H_{3,1} + H_{2,2} = 0 \quad (54)$$

At i=1 , k=2

$$-2H_{1,2} + h_{2,2} - h_{1,3} + H_{2,2} + H_{1,3} = 0 \quad (55)$$

At i=2 , k=2

$$-2H_{2,2} + h_{3,2} - h_{2,3} + H_{3,2} + H_{2,3} = 0 \quad (56)$$

Calculate Electric Field on Surface in Figure 4:

and Rearrange the following "(46)," [5].

$$E_{z(i,k)} - E_{z_{(i,k-1)}} = -j\delta x\omega\mu_0 H_{xg(i,k)}$$

$$E_{z(i,k)} + j\delta x\omega\mu_0 H_{xg(i,k)} - E_{z_{(i,k-1)}} = 0$$

At i=1 , k=1

$$E_{z(1,1)} + j\delta x\omega\mu_0 H_{xg(1,1)} - E_{z_{(1,0)}} = 0 \quad (57)$$

At i=2 , k=1

$$E_{z(2,1)} + j\delta x\omega\mu_0 H_{xg(2,1)} - E_{z_{(2,0)}} = 0 \quad (58)$$

At i=1 , k=2

$$E_{z(1,2)} + j\delta x\omega\mu_0 H_{xg(1,2)} - E_{z_{(1,1)}} = 0 \quad (59)$$

At i=2 , k=2

$$E_{z(2,2)} + j\delta x\omega\mu_0 H_{xg(2,2)} - E_{z_{(2,1)}} = 0 \quad (60)$$

Where the $H_{xg(i,k)}$ is total magnetic field from [5]:

$$H_{xg(i,k)} = H_{xc(x,y)} + H_{xi(x,y)} = \frac{(h-y)I}{2\pi(x^2+(h-y)^2} + \int_0^\infty \phi(u)\cos(ux)e^{-yu}\,du \quad (61)$$

While : $\phi(u) = \frac{I\,e^{-hu}(\sqrt{u^2+j\alpha} - u)}{(\sqrt{u^2+j\alpha} + u)}$ (62)

IV. RESULTS AND ANALYSIS

A. Calculate the electric field intensity in the ground:

Electric field intensity as shown in (E) Fig. 4:

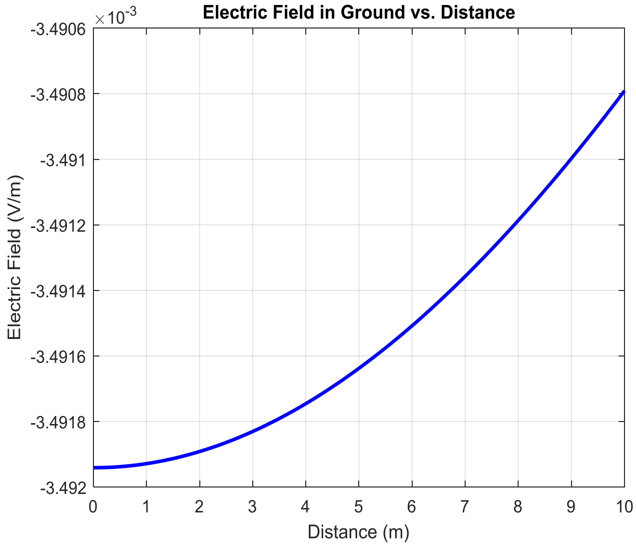

Figure 4. Maximum Electric field intensity in the ground is -0.0034919-0.5077i V/m

B. In Figure. 5 Magnetic field intensity H_{xg},H_{yg} and total magnetic field intensity(H Total)in the in-ground are shown:

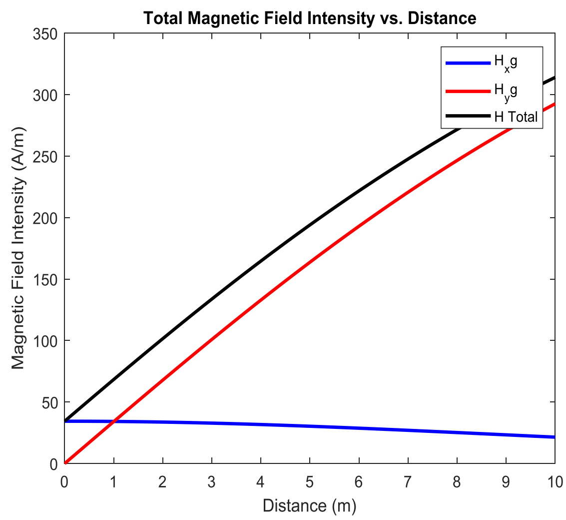

Figure 5. Maximum magnetic field intensity in x-direction (H_xg) is 34.4087 A/m Maximum magnetic field intensity in y-

direction (H_yg)is 292.5003 A/m compared with (H Total) total magnitude vector for magnetic field intensity: 313.9507 A/m in the in-ground.

C. Calculate the electric field intensity on the surface, [10]. Electric power is continuously growing for generation and distribution, it has advanced significantly as a result of a result of reducing the size of electric generators, [9]. Incorporating renewable energy into the generating sector and distributing electricity using power electronics are a few of these strategies. Transmission lines, on the other hand, are an exception to this for calculating the electric field intensity on surfaces it has shown in Figure 6.

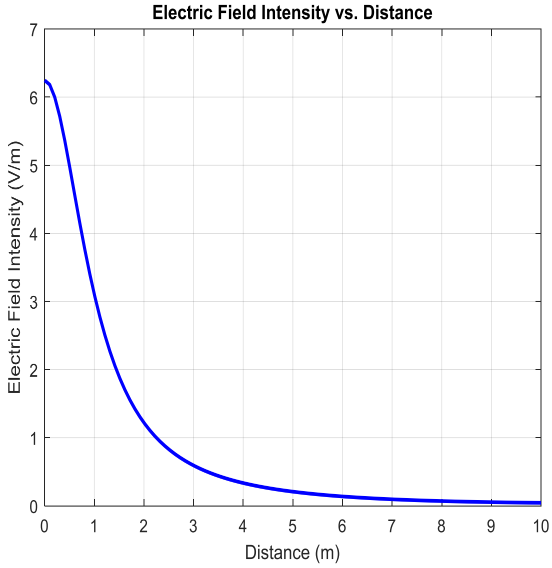

Figure 6. Electric field intensity (E) on surface respect to distance (meters) Maximum Intensity: 6.2463 V/m

A. Figure 7 shows Magnetic field intensity (H) Hxi,Hyi and total magnetic field intensity(H Total) on surface

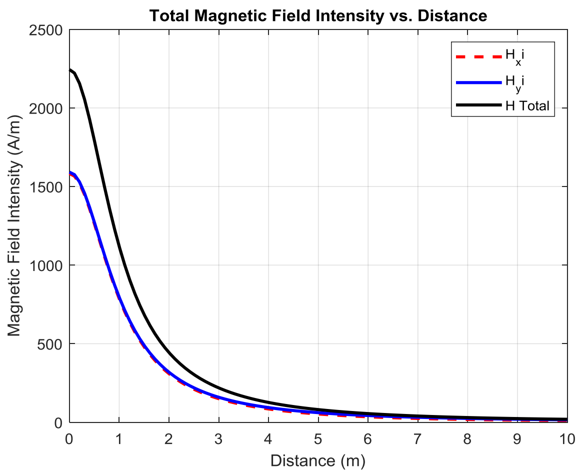

Figure 7. Maximum magnetic field intensity in x-direction (H_xi) is 1582.2181 A/m & Maximum magnetic field intensity in y-direction (H_yi) is 1591.5494 A/m compared with (H_total) total magnitude vector for magnetic field of intensity is 2244.2022 A/m on surface .

CONCLUSION

This paper compares a central finite difference method computational scheme for evaluating electromagnetic field problems in power transmission lines with the high-order compact finite difference method (HOC).

The scheme uses Maxwell's partial differential equations to represent electric and magnetic field components and approximate boundary conditions.

Central finite difference method in Table I has error1 - 0.7224 - 3.8445i, while error2 in Table II showed high-order compact finite difference method (HOC) with 0.0001 - 0.0033i.

HOC gave more accurate results than the traditional central approximation with a level of 99.7% of the exact. For electric and magnetic fields intensity in ground magnetic components Hxg, Hyg and magnetic components Hxi , Hyi on surface has applying only Central difference method because their equations are first order partial differential equation, so no need to applied by High order compact difference method then the applying of FDM showed an increase with distance toward the surface while the effect of fields intensity on the surface with respect to distance was decreased by increasing the distance along the surface.

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