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Dynamic Charging of a Two-Dimensional Model-A PDE Tool Box Application of MATLAB

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Abstract- The PDE Modeler app lets you specify PDE coefficients and boundary conditions in terms of physical entities. For example, you can specify Dynamic Charging of electrical vehicle.

The application mode can be selected directly from the pop-up menu in the upper right part of the PDE Modeler app or by selecting an application from the Application submenu in the Options menu. Changing the application resets all PDEcoefficients and boundary conditions to the default values for that specific application mode.

When using an application mode, the generic PDE coefficients are replaced by application-specific parameters such as Young's modulus for problems in structural mechanics. The application-specific parameters are entered by selecting Parameters from the PDE menu or by clicking the PDE button. You can also access the PDE parameters by double-clicking a subdomain, if you are in the PDE mode. That way it is possible to define PDE parameters for problems with regions of different material properties. The Boundary condition dialog box is also altered so that the Description column reflects the physical meaning of the different boundary condition coefficients. Finally, the Plot Selection dialog box allows you to visualize the relevant physical variables for the selected application.

I. INTRODUCTION -WHAT IS DYNAMIC CHARGING

Wireless Charging Systems (WCS) have been proposed in high-power applications, including EVs, and plug-in electric vehicles (PEVs) in stationary applications. In comparison with plug- in charging systems, WCS can bring more advantages in the form of simplicity, reliability, and user friendliness. The problem or limitation associated with WCS is that they can only be utilised when the car is parked or in stationary modes, such as in car parks, garages, or at traffic signals. In addition, stationary WCS have some challenges, such as electromagnetic compatibility (EMC) issues, limited power transfer, bulky structures, shorter range, and higher efficiency order to improve the two areas of range and sufficient volume of battery storage, dynamic mode of operation of the WCS for EVs has been researched. This method allows charging of battery storage devices while the vehicle is in motion. The vehicle requires less volume of expensive battery storage and the range of transportation is increased. However, a dynamic WCS has to face two main hurdles, large air-gap and coil misalignment, before it becomes widely accepted. The power transfer efficiency depends on the coil alignment and air-gap distance between the source and receiver. The average air-gap distance varies from150 to 300 mm for small passenger vehicles, while it may increase for larger vehicles. Aligning the optimal driving position on the transmitter coil can be performed easily because the car is driven automatically in the dynamic mode. In addition, different compensation methods, such as series and parallel combinations, are employed on both the transmitting and receiving sides to reduce parasitic losses and improve system efficiency. In this review paper, the fundamental operation of WCS for EVs, including methods of power transfer, is analysed. In addition, a variety of wireless transformer structures are explained in order to improve power transfer efficiency. This paper also outlines current developments in the static and dynamic modes of WEVCS in both the commercial and university sectors.

To enable power transfer from the transmission coil to the receiving coil, AC mains from the grid is converted into high frequency (HF) AC through AC/DC and DC/AC converters. In order to improve overall system efficiency, series and parallel combinations-based compensation topology are included on both the transmitting and receiving sides. The receiving coil, typically mounted underneath the vehicle, converts the oscillating magnetic flux fields to HF AC. The HF AC is then converted to a stable DC supply, which is used by the on-board batteries. The power control, communications, and battery management system (BMS) are also included, to avoid any health and safety issues and to ensure stable operation. Magnetic planar ferrite plates are employed at both transmitter and receiver sides, to reduce any harmful leakage fluxes and to improve magnetic flux distribution.

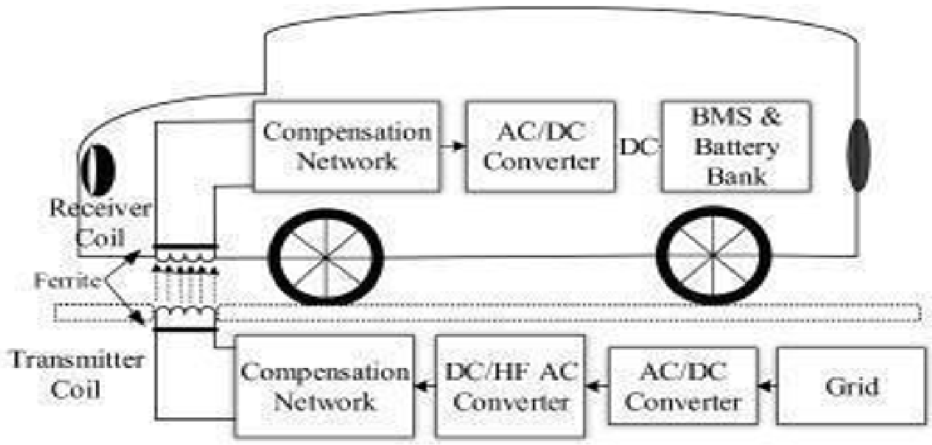

Figure No 1: Dynamic Charging of Electrical Vehicle

II. APPLICATION OF PDE TOOL BOX

Steady and unsteady heat transfer in solids Flows in porous media and diffusion problems Electrostatics of dielectric and conductive media Potential flow Steady state of wave equations Transient and harmonic wave propagation in acoustics and electromagnetics Transverse motions of membranes Eigen value problems are used for:

Determining natural vibration states in membranes and structural mechanics problems In addition to solving generic scalar PDEs and generic systems of PDEs with vector valued u, Partial Differential Equation Toolbox™ provides tools for solving PDEs that occur in these common applications in engineering and science:

Electrostatics and Magnetostatics Structural Mechanics AC Power Electromagnetics DC Conduction, Heat Transfer

III. PROCEDURE OF MODEL SIMULATION

1.1 STEP BY STEP PROCEDURE IN MATLAB

In order to understand our model and simulation methods, we must recognize the applications of Matlab. Matlab is a software that analyze input objects in either in 2D or in 3D mode. Any how input data's should be implemented through system inputs in the form of numbers. Here we have discussed what are the procedures we have followed to develop our model and in which way we have solved it to obtain the simulation results.

1.1.1 Pre-processing in MATLAB

STEP 1: Open MATLAB PDETOOLBOX.
STEP 2: Go to DRAW MODE and create the model as per given dimensions.
STEP 3: Go to boundary condition and select DIRCHILET condition to decide boundary conditions.
STEP 4: Go to PDEMODE and select 'MAGNETOSTATIC' operational mode, then select the 'CURRENT DENSITY OPTION' and 'PERMEABILITY' option to the corresponding values.
STEP 5: Click 'MESH' bottom to generate Mesh diagram.
STEP 6: Solve the PDEMODEL by clicking 'SOLVE' and get the magnetostatics diagram of field vector analysis.

1.1.2 Post-processing in MATLAB

A. Finite Element Mesh with Node Levels

In the above-mentioned procedures after finishing the first 5 steps we will get the CONTOURPLOT along with the MESH PLOT. Once we obtain the MESH

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PLOT again, we will have to click the MESH bottom and select SHOW NODE LEVELS. After that we will get a figure of FINITE ELEMENT MESH WITH NODE LEVELS.

B. Flux lines: obtained by PLOT CONTOUR A

In the above-mentioned procedures after finishing the first 5 steps we will get the CONTOURPLOT by clicking the PLOT bottom and selecting the COLOR CONTOUR PLOT with ARROW in the selections.

1.2 Analysed Problem

The main objective of our simulation methodology is to build a model which can be used for dynamic charging of an electrical vehicle for which we have built a model which has following components:

1. A pair of primary coils
2. A pair of secondary coils
3. A pair of ferrite tiles

Dimensions and current densities of each component are described below:

1.3 Dimensions and Current Densities of Different Components

Dimensions of coil: (0.035 m x 0.035 m) Dimensions of ferrite tiles: (0.186mx0.016m) Length between two coils: .7 meter

Current density of secondary coil: 0
Current density of primary coil: 5*10^6A/m^2Relative Permeability of ferrite tiles: 2200 Absolute Permeability of coil:4*pi*10^-7 H/m

3.4. FINITE ELEMENT MESH

The figure indicates MESH analysis of our proposed model with each node is assigned by anode number or a node level.

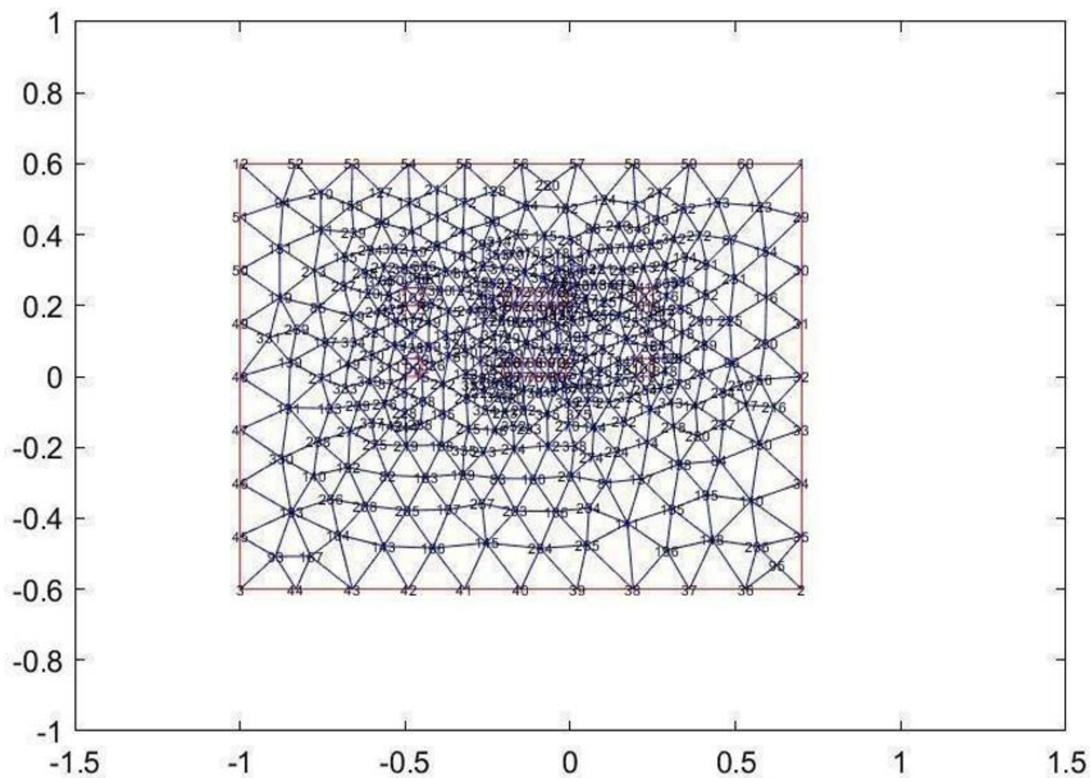

FIGURE NO 2. DESCRIBES THE FINITE ELEMENT MESH POST PROCESSING IN MATLAB WITH DIFFEREN

3.5 MODEL CONTOUR

This figure indicates contour plot of our proposed model in 2-dimensional format with each component is assigned by a given dimension already mentioned in the section 4.1

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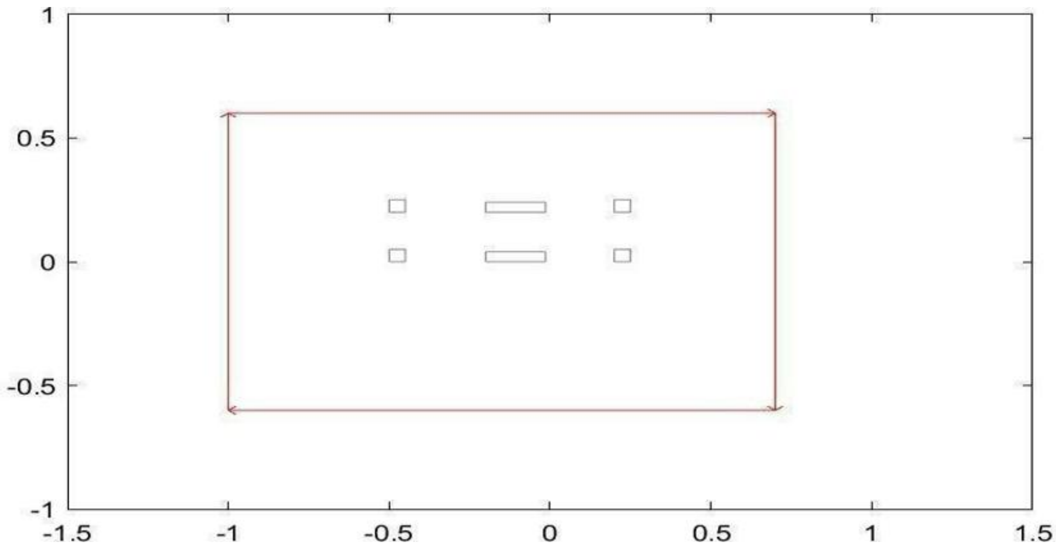

FIGURE NO 3. DESCRIBES THE CONTOUR PLOT OF THE PROPOSED MODEL HAVING JUSTIFIED DIMENSIONS OF

IV. CALCULATIONS AND MATLAB PROGRAMMING CODE

4.1 FORMULAES RELATED TO Emf CALCULATION

Magnetic flux(phi)=(A1-A2) * 1 Wb
A1, A2= Scalar magnetic potentials at the secondary coilsl=Distance between two coils lamda = N*(phi)max*cos(wt) [total linkage] Emf=-d/dt(lamda)=w*N*(phi)max (in Volt/m)

4.2 MATLAB CODES FOR MAGNETIC FLUX CALCULATIONS

After performing all the necessary Step by Step Procedures in MATLAB as mentioned in Section 3 of the report you will have to click on" EXPORT SOLUTION" and find out the number of the no nodes in the primary coils. Once you click the ''EXPORT SOLUTION'' a column of matrix will be generated automatically, from that matrix you will have to find out the value of the nodes of the primary coils according to their numbers given in FINITE MESH PLOT WITH NODE LEVELS. Here we have discussed both the coding techniques for our given model and the model we have generated in a larger boundary box.

4.3 CODES FOR GIVEN MODEL IN MATLAB

*DIFF=U(102,1)-U (101,1) DIFF = 0.0048 L=.7 METERX=DIFF*L*
X =0.0034
*MAGNETIC F L U X =(U(102,1)-U(101,1))*L =.0034 WEB/M*
Lamda=N*Flux*cos(wt+a) total linkageEmf=-d(lamda)/dt=w*N*Flux [V/m]
w=2*pi*f=2*pi*85*10^3 f=frequency=85khz
N=number of turn = 1Emf=w*N*Flux =(2*pi*85*10^3) *1*.0034 =1815.84V/m =1.81584kv/m

4.4 CODES FOR GIVEN MODEL IN MATLAB IN LARGER DIMENSION BOX

*DIFF=U(96,1)-U (98,1) DIFF = 0.0082 L=.7 METERY=L*DIFF*
Y =0.0057
*MAGNETIC FLUX=(U(90,1)-U(98,1))*L =.0057 WEB/M*
Lamda=N*Flux*cos(wt+a) total linkageEmf=-d(lamda)/dt=w*N*Flux [V/m]
w=2*pi*f=2*pi*85*10^3 f=frequency=85khz
N=number of turn = 1Emf=w*N*Flux =(2*pi*85*10^3)*1*.0057 =3042.66V/m =3.042kv/m

V. RESULTS

These are a set of results obtained after performing step no 6 as mentioned in the section 3.1 that is Pre-processing in MATLAB and the whole process is repeated for larger boundary box.

5.1 PLOT AFTER SIMULATION

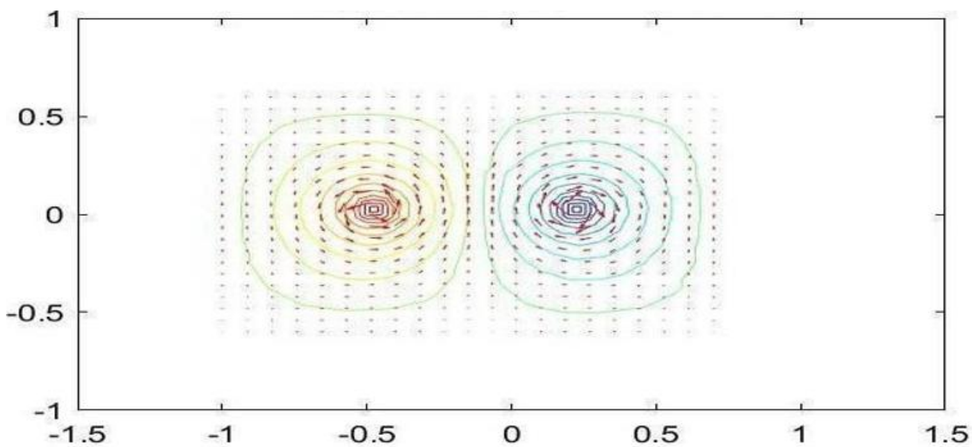

Figure 4 - Flux lines, VECTOR FIELD B OF THE GIVEN MODEL

5.2 PLOT AFTER SIMULATION IN LARGER BOUNDARY BOX

Here is the plot of the above mention analysis of the same model in larger boundary box

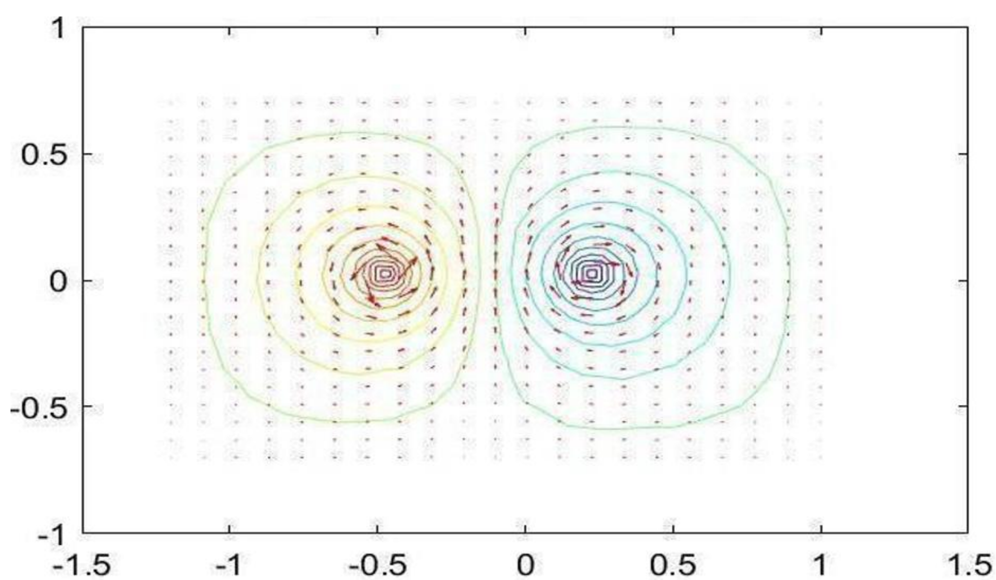

Figure 5- Flux lines, VECTOR FIELD B OF THE GIVEN MODEL IN LARGER BOUNDARY BOX

5.3 Additional Results with Different Current Densities in Secondary Coils

In order to check the efficiency of our model we have decided to perform some additional plots with different current densities in secondary coils;

5.3.1 CURRENT DENSITY IN SECONDARY COIL 3.5 A/m^2

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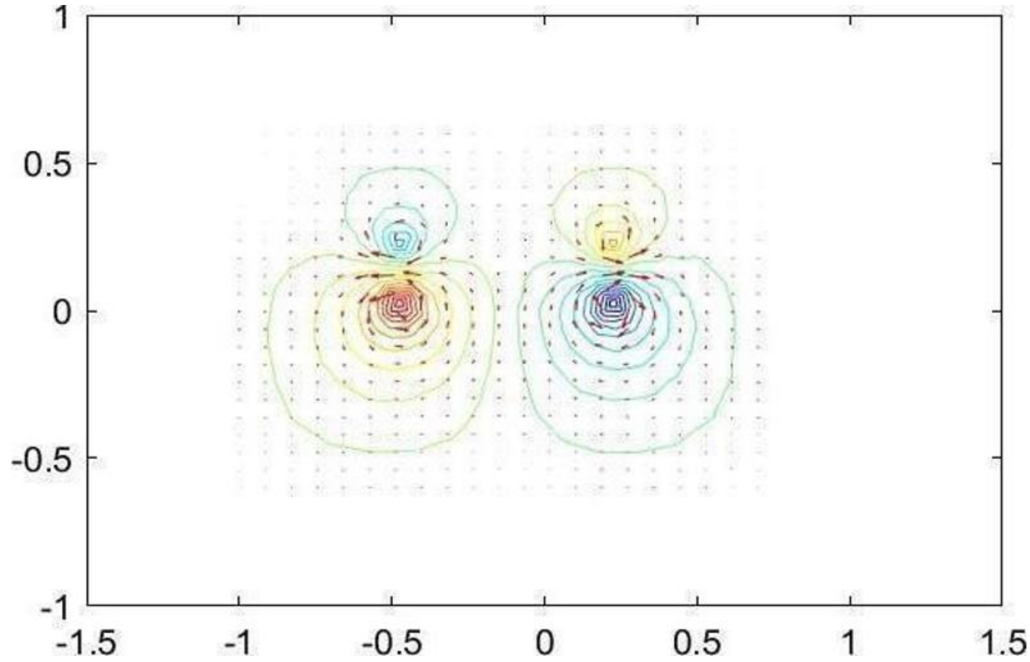

Figure 6- Flux lines, Vector Field B OF THE GIVEN MODEL WITH ABOVE MENTIONED CURRENT DENSITY IN SECONDARY COIL

5.3.2 CURRENT DENSITY IN SECONDARY COIL 4.5 A/m^2

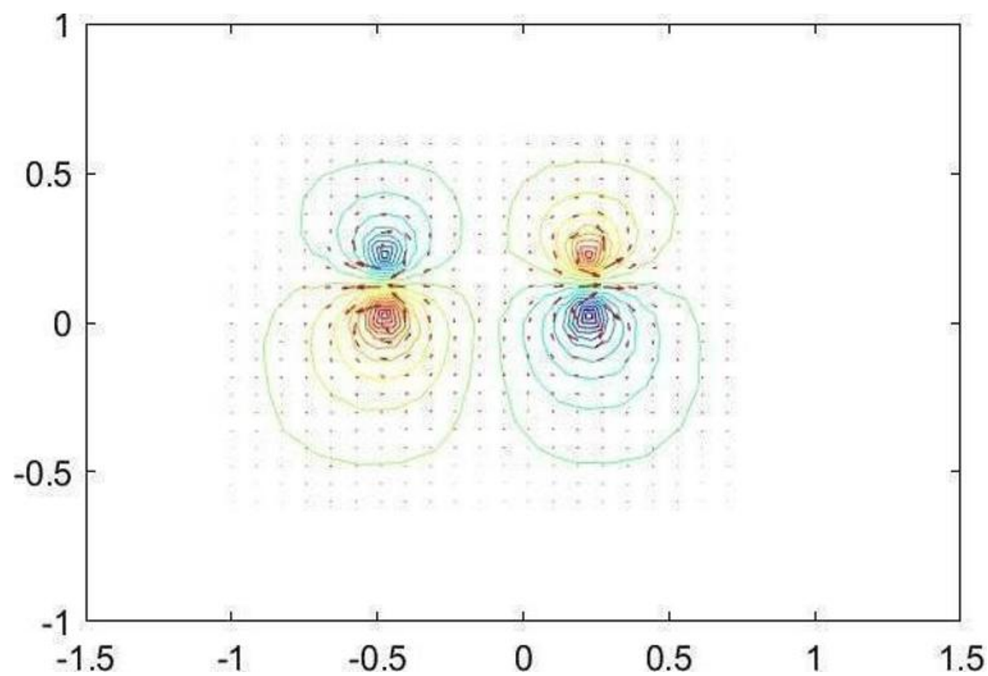

Figure 7- Flux lines, Vector Field B OF THE GIVEN MODEL WITH ABOVE MENTIONED CURRENT DENSITY INSECONDARY COIL

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5.3.3 CURRENT DENSITY IN SECONDARY COIL 5.0 A/m^2

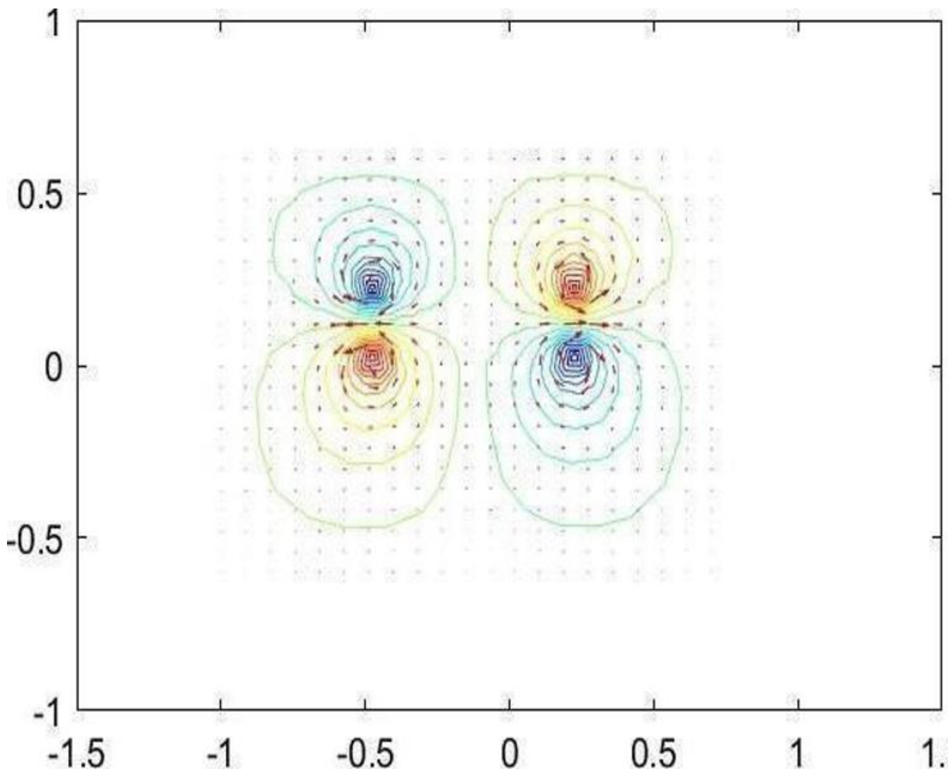

Figure 8- Flux lines, Vector Field B OF THE GIVEN MODEL WITH ABOVE MENTIONED CURRENT DENSITY IN SECONDARY COIL

VI. RESULTS SUMMARY FOR DIFFERENT CURRENT DENSITIES IN PRIMARY AND SECONDARY COILS

To iteratively find a relation between the induced secondary current and the secondary voltage. The aim voltage is 200-240 V.

Results

TABLE NUMBER: 1
10.1 PRIMARY AND SECONDARY VOLTAGES AND CURRENTS

PRIMARY					SECONDARY				
Current density at primary coil (A/m^2)	A1 U(100,1)	A2 U(99,1)	Emf calculated (V/m)	Calculated Emf In Volt [Length*Emf(in V/m)] Length=0.7m	Current density at secondary coils (A/m^2)	A1 U(102,1)	A2 U(101,1)	Emf calculated (V/m)	Calculated Emf In Volt [Length*Emf(in V/m)] Length=0.7m
5.0*10^6	1.0058	.9978	2060.68	1442.48	0	1.0024	.9976	1815.8	1271.08
5.0*10^6	1.0048	.9972	606.64	424.65	2.5*10^6	1.3302	1.3220	432.3	302.61
5.0*10^6	1.0039	.9967	705.87	494.11	3.0*10^6	1.3956	1.3883	405.0	283.5
5.0*10^6	1.0028	.9958	844.58	591.21	3.5*10^6	1.3946	1.3857	398.0	278.6
5.0*10^6	1.0022	.9949	547.73	383.41	4.0*10^6	1.3938	1.3835	384.3	269.01
5.0*10^6	1.0019	.9943	481.73	337.21	4.5*10^6	1.3930	1.3843	326.5	228.55
5.0*10^6	1.0011	.9939	421.63	295.15	5.0*10^6	1.3923	1.3851	266.9	186.83

TABLE NUMBER :2

VII. CALCULATIONS OF POWER EFFICIENCY FROM THE PREVIOUS DATA OFTABLE 1

Current densities usedin Secondary coils (In J) (In Amp/m^2)	Corresponding Values of currents (In Ampere) (I) I=J*A A=4*10^{-6} m^2	CalculatedEmf In Volt in Primary coil (In Volt) (V1)	Power calculationsfor primarycoil (In Watt) (I*V1) (P1)	CalculatedEmf In Volt in Secondarycoil (In Volt) (V2)	Power calculationsfor Secondary coil (In Watt) (I*V2) (P2)	Calculated Power Efficiency E=(P2/P1) *100 (In Percentage)
0	0	1442.47	0	1271.08	0	0
2.5*10^6	10	424.65	4246.5	302.61	3026.1	71.26
3.0*10^6	12	494.11	5929.32	283.50	3402	57.37
3.5*10^6	14	591.21	8276.94	278.60	3900.4	47.12
4.0*10^6	16	383.41	6134.56	269.01	4304.16	70.16
4.5*10^6	18	337.21	6069.78	228.55	4113.9	67.76
5.0*10^6	20	295.15	5902.93	186.83	3736.6	63.30

NOTE: In all cases mentioned in the table no 2 current densities of primary coil in each case is constant that is 5*10^6 Amp/m2

TABLE NUMBER :3

VIII. CALCULATION OF CHARGING VOLTAGE OF THE FERRITE TILES

Our final aim is to find out the charging voltage of the ferrite tiles, so we can see from the table no two that there is a drop between emf in primary and secondary coils as because some amount of emf has been used to charge the ferrite tiles

For each case change in current density in secondary coil generates different charging voltage in ferrite tile that's why emf induced in primary and secondary coils are not same. Here we have used data obtain from Table 2

SL NO	EMF IN PRIMARY COILS (in volt)	EMF IN SECONDARY COIL (IN VOLT)	CURRENT DENSITY IN SECONDARY COIL (AMP/M^2)	CHARGING VOLTAGE IN VOLT= DIFFERENCE BETWEEN EMF IN PROMARY AND SECONDARY COIL IN VOLT
1	1442.47	1271.08	0	171.39
2	424.65	302.61	2.5*10^^{6}	122.04
3	494.11	283.50	3.0*10^6	210.61
4	591.21	278.60	3.5*10^6	312.61
5	383.41	269.01	4.0*10^6	114.4
6	337.21	228.55	4.5*10^6	108.66
7	295.15	186.83	5.0*10^6	108.32

IX. CONCLUSION

So, from our table number 3 we can conclude that our model has been charged for each current density in primary and secondary coils. So dynamic charging is proved by using PDEMODELER, maximum charging voltage is obtained for a current density of $3.5*10^6$ amp/m^2 in secondary coil.

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