Journal of Energy Engineering and Thermodynamics
ISSN: 2815-0945
Vol : 03 , No. 03, April- May 2023
http://journal.hmjournals.com/index.php/JEET
DOI: https://doi.org/10.55529/jeet.33.12.21

Development of Coil Harvesting Energy from the Ambient Magnetic Field

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Received: 27 January 2023 **Accepted:** 06 April 2023 **Published:** 12 May 2023

Abstract: Energy Harvesting from Magnetic Fields has been a popular study topic in recent years since it provides a sustainable and environmentally friendly alternative to existing power sources. The goal of this project is to design and construct a device for collecting energy from an ambient magnetic field using the principle of electromagnetic induction. The gadget will be made up of a magnetic coil. The energy harvester's performance will be examined and adjusted depending on numerous factors such as coil design. IoT gadgets, wearable technology, and remote systems are examples of IoT devices. In this project, a toroidal core voltage is induced in the coil, which is then delivered to the energy storage system and utilised to power IOT systems.

Keywords: Energy Harvesting, Magnetic Field, IOT, Core.

1. INTRODUCTION

Energy Harvesting from Magnetic Fields has been a popular study topic in recent years since it provides a sustainable and environmentally friendly alternative to existing power sources. The goal of this project is to design and construct a device for collecting energy from an ambient magnetic field using the principle of electromagnetic induction. The gadget will be made up of a magnetic coil. The energy harvester's performance will be examined and adjusted depending on numerous factors such as coil design. IoT gadgets, wearable technology, and remote systems are examples of IoT devices. In this project, a toroidal core voltage is induced in the coil, which is then delivered to the energy storage system and utilized to power IOT systems. [1][2][3][13]

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Theory

The technique of absorbing lesser amounts of magnetic energy from the environment and transforming it into useful electrical power is referred to as energy harvesting. The project's focus is on magnetic field energy harvesting. The objective is to create a technology that can convert magnetic field energy to electrical energy effectively. This will be accomplished by using it in several applications. The device's performance will be evaluated by measuring the output voltage and current under various magnetic field strengths. The project's findings will contribute to the improvement of energy harvesting technology and battery- free technologies.[1][15][4][7]

System Design

LT spice is a simulation software for simulating circuits.LT spice will provide a waveform viewer to show the results of the simulation. LT spice is capable of simulating both analogue and digital circuits, and it contains a wide selection of circuit components such as resistors, capacitors, inductors, diodes, transistors, and operational amplifiers. It also has built-in models for a wide range of semiconductor devices, including MOSFETs, BJTs, JFETs, and IGBTs.[15][16]

Proposed Energy Harvesting System

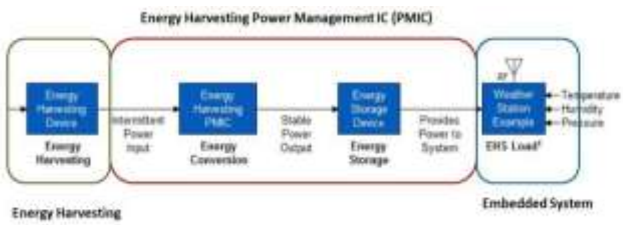

Figure 1

1) **Energy Harvesting Device**
   The Energy Harvesting Device contains core of silicon steel material with wounding of copper coil. Energy Harvesting section the coil would harvest the energy from the transmission line of the magnetic field. The energy induced will be given to an energy conversion unit.[2]

2) **Energy Conversion**
   A Full Wave Rectifier is a rectifier that transforms the whole cycle of an alternating current (AC) signal into a pulsing direct current (DC) signal.[1]

3) **Energy Storage Device**
   Supercapacitor would be used it will range from few milli Farad to Farad. It will charge up amazingly fast and discharge to power up the components.

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4) **Embedded System**
This embedded system could be temperature sensor, pressure sensor, humidity sensor, etc. [1]

Theoretical Readings for Toroidal Core
To clarify the characteristics of the proposed, the theoretical calculations table is made below for toroidal core.
$v = h u_0 u_r n f I \omega \, ⅆ \ln(1 + \omega)$

Input Parameters	Toroidal Coil
Height, (h)	0.01
Number of Turns, (n)	1320
Permeability of free space, (u_0)	1.25664E-06
Relative Permeability, (u_r)	1500
Frequency , f(Hz)	50
Current from the conductor, I (A)	750
Width of the Core ,ω (m)	0.005
Distance from Conductor to Coil,d (m)	0.02
$\ln(1 + \omega)$ Width of the core	0.004987542
Height*Turns*Permeability*Relative permeability*Frequency*Current* Distance from conductor to coil	18.6610446
Voltage (v)	0.093072735

The above input parameters will be used to obtain induced voltage across the toroidal shaped core with 1320 turns.

Experimental Lab Setup
The silicon-steel core is seen in the figure below.
With 1320 turns of enameled copper wire on the toroidal geometry

Figures and Table

Silicon-Steel Core
Figure 2

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The silicon-steel core is seen in the figure above.
With 1320 turns of enameled copper wire on the toroidal geometry.
In to fully understand the suggested energy harvesting system, we need to measure the voltage induced in the core, which can be obtained from the magnetic fields of the AC powerlines.[8][10][11]

Experimental test lab setup
Figure 3

Experiment Oberservations
Toroidal core practical readings, the coil is kept at 2cm distance from the transmission line, the current is passed from the transmission line in amperes.[14]

Geometry	Voltage Induced	Distance	Amperes(A)
Toroidal	20mV	2cm	200
	44mV	2cm	500
	60mV	2cm	750

Digital Multimeter
A digital multimeter is a piece of test equipment that combines numerous electronic measuring tasks into a single device. It is sometimes referred to as a voltmeter, Ohm meter, or Volt Ohm meter. The standard and fundamental measurements performed by a multimeter are amps, volts, and ohms.

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Digital Multimeter
Figure 4

The above is the output from the digital multimeter readings for the experimental observation for 750A, at 2 cm from the transmission line, the output of 60mV is obtained at the output.[4][5][6][7]

Comparison of 8500,15000,4400 Turns Cores

Current(A)	Vrms(V) 8500T_20 Ω	Vrms (V) 15000T_13 Ω	Vrms(V) 4400T_10 Ω
20	0.012	0.024	0.001
60	0.042	0.051	0.004
100	0.078	0.095	0.007
140	0.12	0.153	0.011
180	0.165	0.214	0.016
220	0.212	0.279	0.02
260	0.259	0.341	0.025
300	0.306	0.401	0.03
340	0.352	0.46	0.035
380	0.396	0.519	0.04
420	0.44	0.575	0.043
460	0.483	0.617	0.048
500	0.523	0.683	0.052
540	0.564	0.738	0.056
580	0.603	0.785	0.06
620	0.643	0.833	0.064
660	0.682	0.883	0.068
700	0.72	0.928	0.072

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740	0.755	0.97	0.075
780	0.79	1.06	0.079
820	0.824	1.08	0.082
860	0.858	1.12	0.088
900	0.891	1.15	0.091
940	0.923	1.2	0.094
980	0.955	1.24	0.097
1020	0.986	1.29	0.099
1060	1.017	1.32	0.102
1100	1.046	1.36	0.105
1140	1.076	1.4	0.107
1180	1.105	1.44	0.109
1260	1.169	1.51	0.118
1300	1.195	1.54	0.121

Graphical Representation Of The 8500t,15000t,4400t Cores V-I Characteristics

Figure 5

The Proposed Cylindrical Core Design

The most efficient technique to capture magnetic energy at 50/60 Hz is to use coils wrapped around Silicon Steel cores. Even though the coil is not immediately clamped on a current, the entire system is still an inductive coupling circuit. The analogous circuit of a harvesting coil coupled to a matched load is shown in figure 6. The voltage induced by the coil Vcoil is a function of the surrounding magnetic flux density and the coil characteristics, as illustrated in figure,

$Vcoil = N\omega BexA\mu eff$

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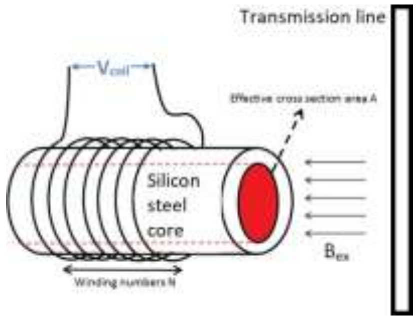

Cylindrical Core
Figure 6

where Vcoil is the RMS (root mean square) voltage of the AC waveform, N is the number of turns twisted on the coil, Bex is the external magnetic flux density in Trms applied to the coil, and A is the area of the core, A denotes the coil's effective cross section area in m2, ω is the angular frequency in rad/s, and μeff is the effective permeability linked to the core material and core shape.
This process is utilized as the magnetic flux density in both the software simulation and the experiment in this study.[3][4][12]

Theoretical readings for cylindrical core
To clarify the characteristics of the proposed, the theoretical calculations table is made below for cylindrical core [13][1]

$Vcoil = N\omega BexA\mu eff$

Input parameters	**Cylindrical core**
Number of turns (N)	4600
Angular frequency, radian (ω)	314.15
Permeability of free space, (U)	1.25664E-06
B(Magneticfield)U*(I)/(2*3.1415*r) (T)	0.0004
Area of the Core, m^2	0.00031415
Effective Permeability(μeff)	32
Distance from the conductor, r (m)	0.025
Frequency, f (Hz)	50
Current through conductor, I (A)	50
Radius of the core, R (m)	0.01
Vcoil, (V)	5.810880301

Simulation Circuit
For the proposed design of the Cylindrical Core the simulation circuit is performed for energy harvesting.

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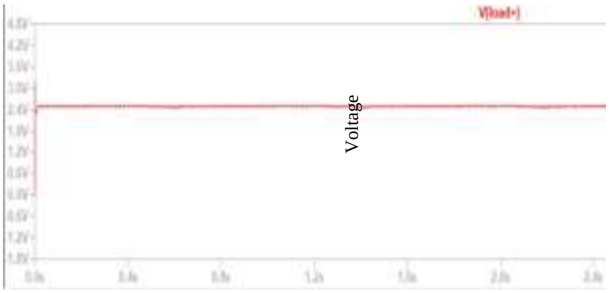
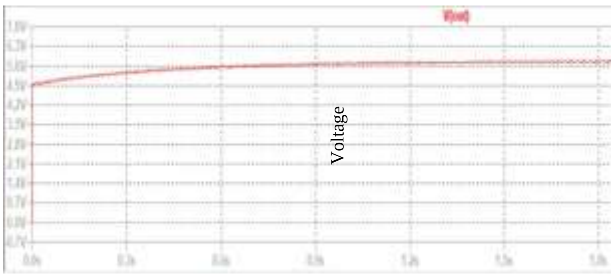
For implementing magnetic energy harvester, the current transformer is used in this circuit with the core connect to the full wave rectifier, the output of the full wave rectifier is given to the super capacitor. The LT 1371 is used as booster in the circuit .LT 1371 would boost the input from the super capacitor of 2.5v to 5.75v [15][16]

The Output Across the Super Capacitor 2f (Full Wave Rectifier And Storage Capacitor)



Time
Figure 9

The Output Across The Lt1371 Voltage Booster



Time
Figure 10

2. CONCLUSION

With the toroidal core, the voltage induced 60mV, with 1320 turns of enameled copper wire on the toroidal geometry at 750 A.

The current passing from the transmission line and number of turns around the cores play a significant in voltage induced in the core. The theoretical calculations and the practical readings for toroidal core are compared.

The proposed design of cylindrical core with theoretical calculations and LTspice simulations, for 5.81v and 5.75v are performed. Future extension will include integrating an energy collecting system using easily accessible modules and developing a better gadget.

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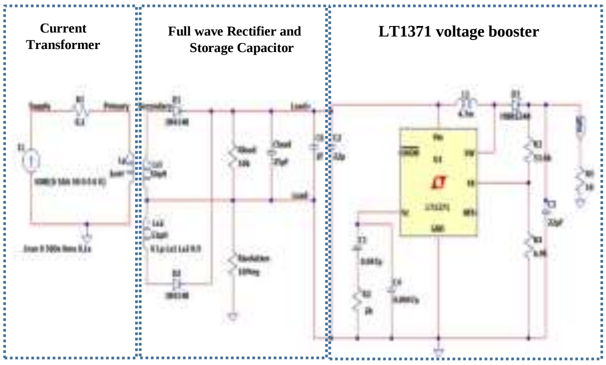

Figure 7

The Input Waveform in the Simulation Circuit with 50a as the Input on the Transmission Line
(Current Transformer)

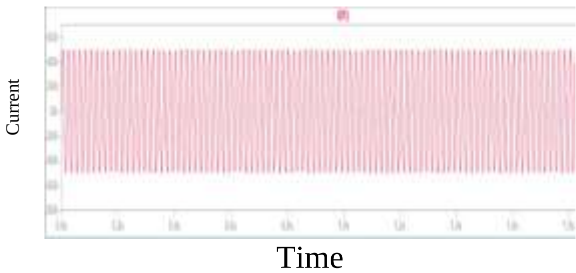

Figure 8

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