Utilization of Effective Leakage flux using Wireless Power Transmission in Induction Stove

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Abstract--- *This paper implements the concept of Wireless Power Transfer (WPT) between the two coils related to the induction stove. At the time of cooking, the oscillating magnetic flux in the induction stove used to cook the food. Here a thin circularly wounded flat coil kept in between the induction stove and the cookware. So, EMF gets induced in a coil based on Faraday's law of an Electro-Magnetic Induction (EMI). This Electro-Motive Force (EMF) used to charge a battery that can be used as an emergency power source or directly connected to the load. Also, the leakage flux of the induction stove is utilized by a load with the help of a flattened copper coil. This prototype also explains the WPT and gives an idea in real-time applications.*

Keywords--- *Alternating Current (AC), Electric Power Research Institute (EPRI), Electro-Magnetic Induction (EMI), Magneto Motive Force (MMF), Wireless Power Transmission (WPT).*

I. INTRODUCTION

In our India, due to the subsidy slash in Liquefied Petroleum Gas (LPG) cylinder for domestic purpose, some of the people move to induction stove for cooking purposes. In our day-to-day life, electricity plays an important role for all consumers. The demand for electricity is increased proportionally to the growth of the present population. The major drawback of the transmission and distribution system is its maintenance and various losses around 26-30% with 70-74 % efficiency. So, development is necessary for the present scenario. The flow of electrons is essential to drive electronic instruments and cooking appliances. Here the domestic level induction stove is used to implement a prototype of Wireless Power Transmission (WPT).

The working of an induction stove can be obtained from the principle behind the transformer. The coil in the induction stove and cookware is magnetically coupled as primary and secondary coils of a transformer. The current is flowing in the cooking vessel (Eddy current) due to the low resistance of the cookware; with power dissipation is given by I^2R. The opposition of the vessel is dependent on the inductive permeability (μ) and resistivity (ρ) of the cookware, just as the frequency of excitation. To produce adequate heat for cooking, the cookware must be utilized that has generally high permeability and resistivity. Also, the switching frequency of a stove is in the range of 10 kHz to 50 kHz. It is very important for the analytical analysis for the optimization and design of the heating coil of an Induction cooker. In the transformer, the problem is associated with the core is called core loss and eddy current loss. These losses will be further explained below,

1) Skin Effect Loss
2) Proximity Effect Loss

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1. 1. Skin Effect Loss

When an Alternating Current (AC) flows through the copper conductor a sinusoidal magnetic flux is produced in and around the conductor and flux is vertical to the conductor axis when skin effect occurs. The eddy current is produced in the conductor and it flows opposite to the main conductor current. The net current is reduced at the center of the conductor it gradually reduced exponentially from the outer surface of the copper conductor. In a solid copper conductor, the skin effect is high when it is compared with strands copper conductor. To avoid this drawback strands copper conductor is used in the Induction cooker. This skin depth is the function of frequency, permeability, and conductivity of the conductor materials. Skin effect depth is normally expressed as $\delta = \frac{1}{\sqrt{f\pi\mu\sigma}}$, where f is the operating frequency, μ is the permeability of the conducting material, σ is the conductivity of the conducting material. For a copper conductor $\delta = \frac{0.066}{\sqrt{f}}$ meter. Eddy current increases with the increase in frequency; as a result, conduction loss is also increased.

1.2 Proximity Effect

In domestic usage of an induction heating cook top, the spiral-shaped heating coil is used. The Proximity Effect is occurring due to the generation of the magnetic field is surrounded by the conductors in the coil. It is divided into two types, there are (i). Internal proximity effect and it is the effect of the other current within the bundle. (2). External proximity effect and it is the effect of current in other bundles. The eddy current is proportional to the frequency of the magnetic field. By increasing the frequency, the losses are associated with eddy current also increased. In induction stove, eddy current is important to produce heat. While turning ON the induction stove the circuit in the induction stove produces a high-frequency AC that makes a high frequency alternating magnetic field in terms of 24 kHz in the coil. This high frequency alternating magnetic field will have the ability to produce eddy current in the vessel. This current circulates towards the pan and produces heat in the pan and cooks the food.

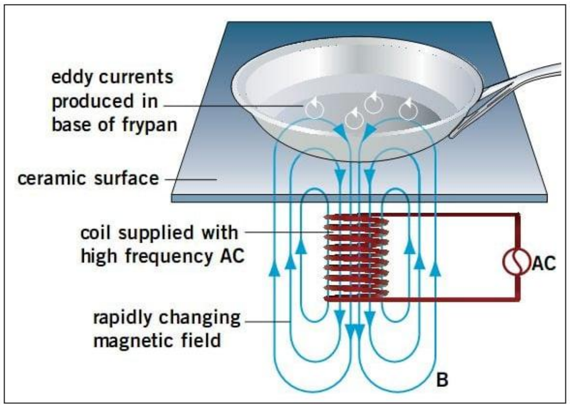

Fig. 1: Eddy current

II. Technology Of Power Transfer

Here, the prototype consists of a secondary flattened coil to recover electricity from the stove to reduce the troubles associated with that. Here, electric power from one circuit is transferred to another circuit without having any physical connection between the circuits but through a magnetic field. Types of wireless power transmission are shown below,

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Table 1: Types of WPTT

Transmission	Types
Short Transmission	1) Electromagnetic Induction method • Magnetic Induction • Magnetic Resonance
Long Transmission	1) Microwave method 2) Optical method

In the short transmission method, the Magnetic Induction type is used for electric energy is transformed into magnetic energy by an inductive coil. The flux is produced in that coil will induce an EMF in the nearby coil. In magnetic resonance type both electrical circuits (i.e. transmitter and receiver) tuned into the same frequency, so that maximum energy can be transmitted.

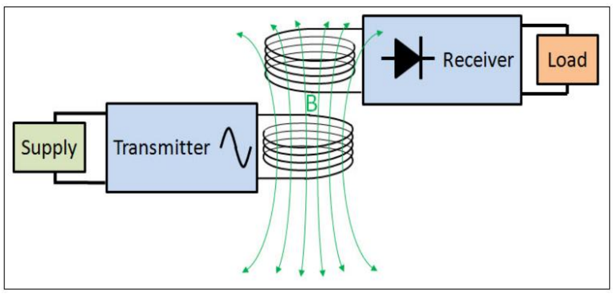

Fig. 2: Wireless Power Transfer

In the long transmission method Microwaves that have the property of highly directional, the shorter wavelength is used. Rectenna is used to convert it back to electricity with 95% efficiency. It has an inherent ability to travel over a long distance. So that it is used to transmit electric energy wirelessly.

In the Optical method, a high-intensity laser beam in the visible region used. The velocity of the LASER is more than the light. i.e 3×10^8 meters per second. This is excellent to travel over a very long distance. Photo Voltaic (PV) cells are used to convert the light back to electricity. In the domestic level induction stove, electric power converted into heat energy. An oscillating magnetic flux created in the induction stove won't be changed over into thermal energy. A little leakage flux related to that we are utilizing a dish having a distinctive base surface for preparing food, heat the water, get ready any type of food and so forth. The vessel that we are utilizing in the induction stove in everyday life does not have a similar base zone. The base surface region of a dish is little contrasted with the surface zone of the coil inside an induction stove. In this model electric energy is changed over to heat energy just as recouped back to electric energy as leakage flux related to it. The cooking efficiency testing made by Electric Power Research Institute (EPRI) and every one of the customer cooking apparatus as per the enlistment perfect test system it created, including the warming of water from 100° to 240° F (37° to 115°C). Trials were performed with every gadget at both half power and full control, with proficiency determined as the normal of the three runs.

The results are shown below,

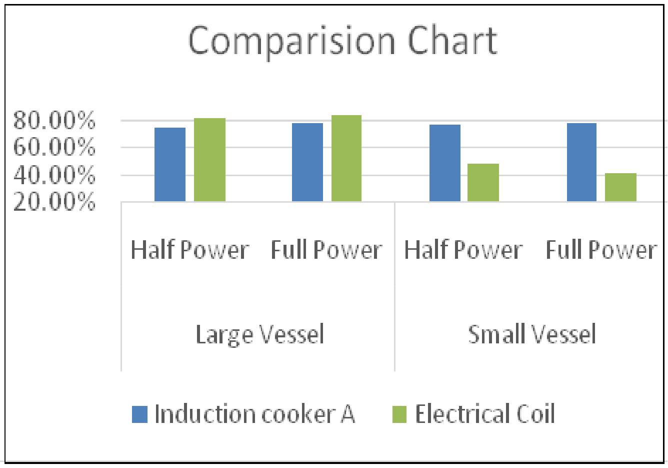

Chart 1: Comparison of a large vessel and small vessel characteristics

III. EXPERIMENTAL SETUP

The induction stove having a specification of 220V AC and a power rating of 1600 W is used in this model. Voltmeter and ammeter are connected in the input side and output side used to measure the input quantity and corresponding output quantity. The input of 220 V, 1ph, 50 Hz supply is used. The basic circuit diagram is shown in fig.

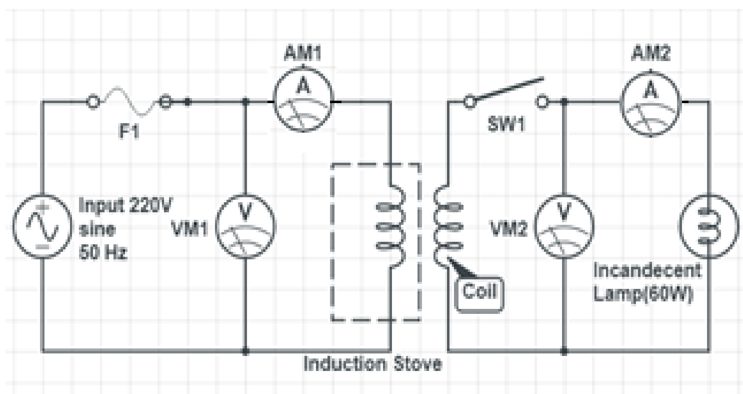

Fig. 3: Coil with lamp load

In this experiment, three types of flattened coils are used and each one has a different Standard Wire Gauge (SWG). The thickness of the coil is 21, 23, 25 SWG. These coils are shown in fig.,

Fig. 4: Coils having different SWG

Each coil consists of one secondary coil both have 20 turns. The circumference of the main and sub coil is 34.54 cm and 25.12 cm respectively. The total length of the conductor is used in this coil is 1200 cm. The output of the coil having different SWG is analyzed for minimum, medium, and maximum temperature of the stove. The lamp load of 60 W is connected to the output side.

The emf is induced in the coil is that

$EMF = -Nd\emptyset/dt$ Volts

Where, N= Number of turns in the flat coil, $\emptyset$ = Magnetic flux from the primary coil. If the numbers of turns in the coil are increased EMF produced in that also increased. The negative sign denotes Lenz's Law, where the generated EMF has the opposite sign.

3.1 Working

To measure the voltage across the terminal of the coil voltmeter having in the range of (0-250V) Moving Iron (MI) is connected parallel to the setup. To measure the current, ammeter having in the range of (0-2.5 A) is connected in series to the rectifier output.

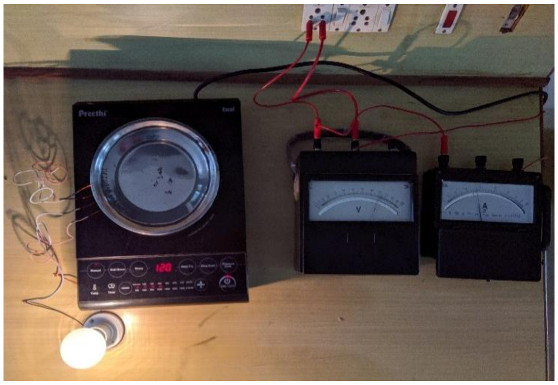

Fig. 5: Typical setup of this prototype

The frequency of this field is in the range of 100Hz to 50 kHz. This produces induced EMF in that coil with the same frequency that looks the same in the transformer. The typical frequency waveform of the commercial supply of 50 Hz and 1 kHz simulated in Lab VIEW 2016 shown below,

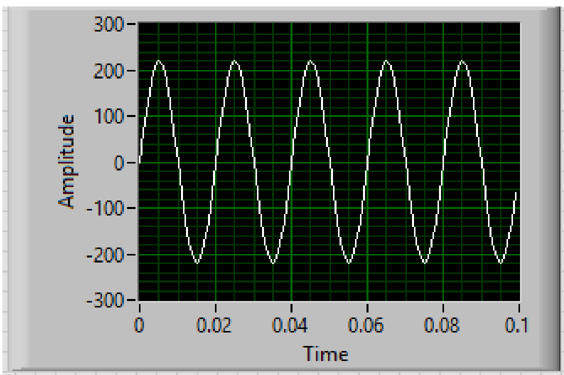

Fig. 6: 50 Hz Frequency Waveform

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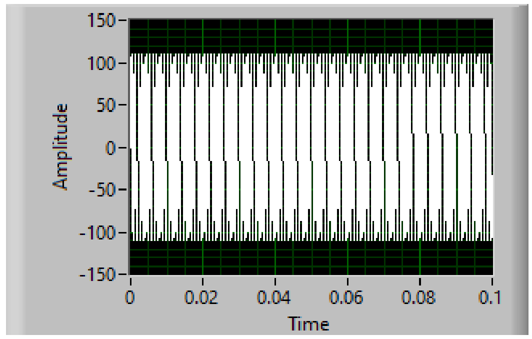

Fig. 7: Frequency Waveform of 100 Hz.

But, this is not reliable to drive a conventional AC load, because of high frequency. High frequency voltage affects the circuit components. To use the recovered power effectively, convert it into a DC and utilized to drive the DC loads. But, it is reliable to operate a little DC load for helpful activity, like charging of 12V DC battery to be employ as an emergency LED in kitchen.

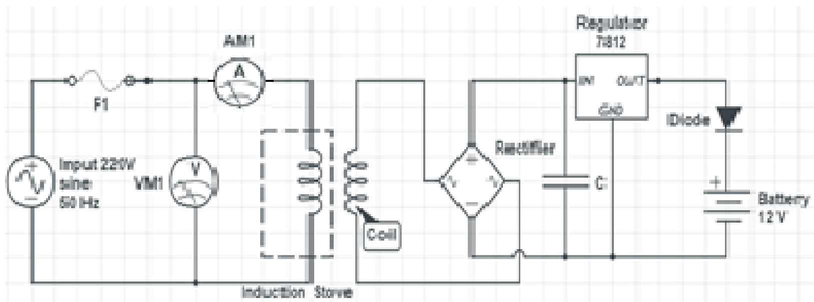

Fig. 8: Charging Circuit of 12V output.

By interfacing, the above circuit to the output coil will charge the battery at whatever point the induction stove is turned ON. The flowchart of this examination as well demonstrated as follows

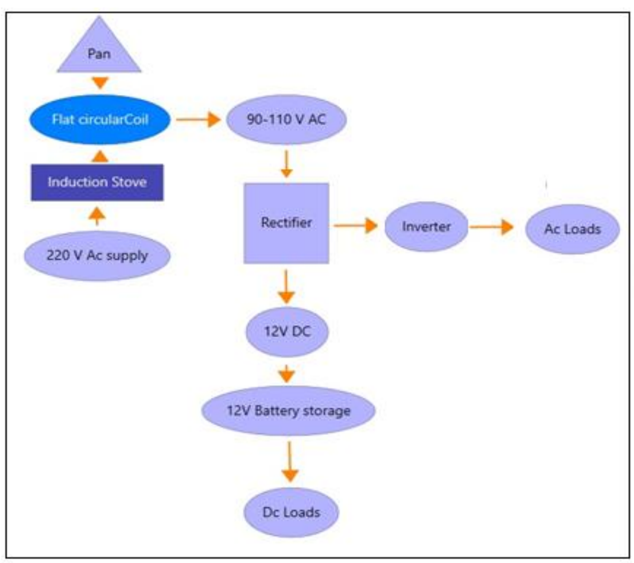

Fig. 9: Flow Chart of the System

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IV. RESULT ANALYSIS

By analyzing the voltage and current, the typical values of output in the coil are shown below,

Table 2: Input parameters for the thickness of the coil

COIL SIZE	TEMP In °C	INPUT		
		VOLTAGE In Volts	CURRENT In Amps	POWER In Watts
21 SWG	37.7	230	4.5	931.5
	82.2	228	5.1	1046.5
	115	220	7.5	1485
23 SWG	37.7	222	4.65	929
	82.2	220	5.2	1029.6
	115	170	8	1224
25 SWG	37.7	220	4.7	930.6
	82.2	218	5.2	1020.2
	115	170	8	1224

The relation between an input voltage and current is shown below,

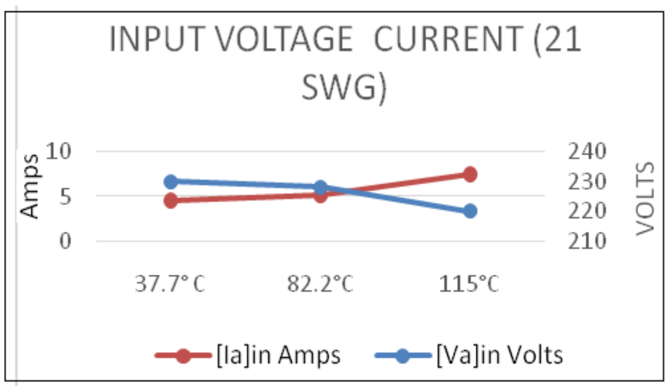

Chart 2: V-I characteristics of an input

The emf induced in 21, 23, 25 SWG coil and at different induction stove temperature of 37.7°, 82.2°, 115° Celsius with a different type of loads are observed and shown below, For the values are taken, the graph is plotted for voltage, a current is shown below,

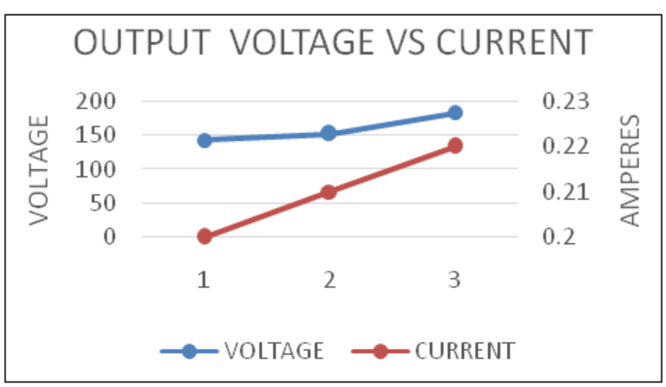

Chart 3: V-I characteristics of Output

Table 3: Output power in DC estimated in different thickness of the coil

COIL SIZE	**TEMP In °C**	**DC OUTPUT**		
		VOLTAGE In Volts	**CURRENT In Amps**	**POWER In Watts**
21 SWG	37.7	143	0.2	28.6
	82.2	152	0.21	31.92
	115	183	0.22	40.26
23 SWG	37.7	147	0.19	27.93
	82.2	156	0.20	31.2
	115	198	0.21	41.58
25 SWG	37.7	147	0.18	26.46
	82.2	156	0.19	29.64
	115	199	0.20	39.8

The current increased proportionally to the thickness of the coil.

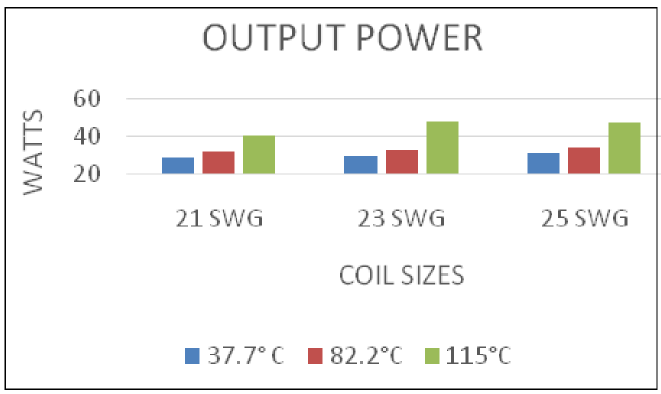

Chart 4: Output Power

By observing the graph power output is increased corresponding to the thickness of the coil.

V. CONCLUSION

By observing the prototype, the coil recovers 2-3 % of the energy of the input side. We may have inquiries like "Is the coil will go about like a load to the induction stove" This arrangement is the test model of actualizing wireless power transfer technique and if the load that associated with that coil which is put on the stove over as high as possible, it takes more power from the input that builds the general power contribution of the induction stove that diminishes the productivity of the stove. Such a method does not catch extra misfortunes that might be normal in real use. Finally, it found that the improvement of the flattened coil is good with induction cooking and also the paper obviously clarifies the idea of the wireless power transfer technique of the induction stove.

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