PROPERTIES OF INDUCTORS (INDUCTANCE) AND ITS APPLICATIONS TO INDUSTRY

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ABSTRACT

This study seeks to determine the magnetic polarity of different power sources, to prove the relationship of inductors/inductance to electromagnetism and correlate the principles with the applications in the field of industry. The dimming of the lamp in the circuit was identified by adapting the Jet Propulsion's Laboratory method and to know the reasons behind it when the core in the inductor was inserted. This study devised a circuit in place of the current sensing resistor and substituted it with lamps. As the procedure requires, voltages across the lamps and in the inductor as well as with the source were correlated vectorially. Tests were conducted at different lamp combinations and different core positions. The dimming of the lamp was caused by the current limiting characteristics of the inductor. When it comes to magnetic polarity, AC source has no specific polarity while DC source has a very distinct polarity. The reaction of the repulsion coil was caused by mutual inductance wherein the short-circuited coil creates a magnetic field opposing the inductor which causes the coil to repel. These simulates what happens in Maglev trains, system protection in power industry, induction heating in metallurgy as well as semi conductor industry and the catapulting of low orbit satellites.

INTRODUCTION

The phenomenon behind the dimming of incandescent lamp in series with an inductor with variable iron core is a wonder. The inductor made of coils of magnet wire on a bobbin with or without a magnetic core. This study seeks to device a circuit that would identify whether inductors or inductance (impedance) causes the cited phenomenon. This study aimed to define magnetic polarity properties when connected to different power sources (Alternating and Direct Current); investigate the relationship of inductors/inductance to its internal resistance in determining its pure inductance value; and correlate the findings by simulations on its significant applications in the field of industry like the power industry, rail transportation, metallurgy, etc.

This study was conducted purely on AC circuit test. Construction and all tests were performed under a technical adviser's supervision for safety because the circuit was tested on live 220V AC power source. Testing the DC source was only made on polarity since the DC rectifier power supply doesn't have a filter. The study is only limited to the improvised circuit constructed and the variables studied (mutual inductance, resistance, impedance etc).

DC current flowing through a long wire produces a circulatory magnetic field around the conductor. Magnetic field has polarity and that when the current is reversed the magnetic field will follow the current reversals. With the multitude of wire turns the coil exhibits a magnetic field greatly intensified. Like a bar magnet, the coil has a north and south pole and a neutral center region. Moreover, the polarity can be reversed by reversing the current I through the coil. This again demonstrates the dependence of the direction of the magnetic field on the current direction (McLyman. 1988).

METHODOLOGY

A modified circuit was devised by which 3 lamps in parallel were connected in series with an inductor. The circuit devised was somewhat similar to the Jet Propulsion Laboratory (JPL) circuit in the magnetic component test for the measurement of inductance (McLyman, 1988).

In the JPL procedure, the current sensing resistors are of fixed value resistors and the inductors

to be tested are fixed cored inductors. The circuit in this study, incandescent lamps served the place of the current sensing resistor. The lamps to be on were of different combinations and the inductor with variable core positions.

Adapting the JPL magnetic component test circuits (McLyman, 1988) for the measurement of inductance, for each combination of incandescent lamps switched on, measurable electrical values were taken on each respective sequential positions of the iron core in the inductor.

To measure the inductor current in the reactor,

$$I_L = \frac{V_{B5}}{R} \qquad (1)$$

is used. Reactance of the reactor is calculated through

$$X_{L5} = \frac{V_{5A}}{I_L} \qquad (2)$$

and inductance is measured by

$$L_{5A} = \frac{X_{L5A}}{2\pi f} \qquad (3)$$

where f = 60Hz, the power source frequency.

The calculated values of I_L and L_{5A} were graphically plotted to analyze the dimming of the incandescent lamps as the core was inserted in the inductor.

Other magnetic properties of the inductor were studied and observed: magnetic poles on the inductor when AC and DC power were energized; mutual inductance with a short-circuited coil; and the heating of the core. From these principles simulation were made to correlate the product applications of inductors in the power industry, metallurgy, semi-conductor industry, rail transportation and aero-space.

RESULTS AND DISCUSSION

Effect of Inductance to the Incandescent Lamp

Testing AC source, dimming of the incandescent lamps was observed. Measurement of current, voltage and resistance was done to determine the inductance (Figure 1). The indications were the iron core for its permeability increases the inductance. With AC power source, any circuit that carries a varying current has an induced electromotive force (emf) in it resulting from the variation in its own magnetic field or self-induced emf. This is what inductance is; choke acting in opposition to the flow of current. Inductors or reactors are current limiting electrical circuit components.

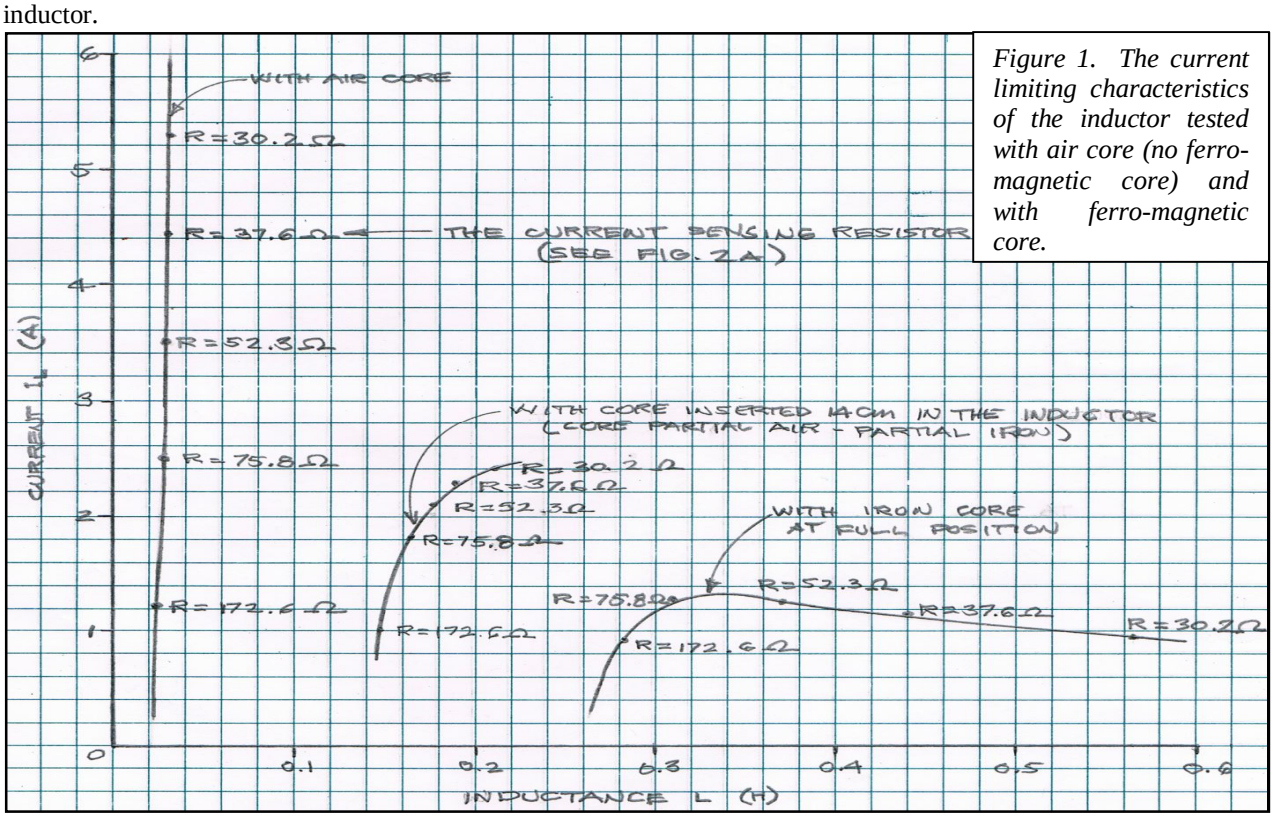

Figure 1. The current limiting characteristics of the inductor tested with air core (no ferro-magnetic core) and with ferro-magnetic core.

Magnetic Polarity

When AC power is energized, the magnetic compass needle did not respond or doesn't change its direction. The core was at full core position, the compass needle responded to one end of the inductor without distinguishing any polarity. The north and the south end of the needle were attracted by the same end of the inductor.

When DC power is energized, the compass needle responded direction wise. One end of the inductor was in north and the other was in south. The direction is always south is south and north is north.

In both cases of power source applied, the compass needle was strongly attracted when the inductor was with full core compared with no core or air core.

Heating of the Core

Throughout the experimentation, the core temperature rose to relatively high level and is felt by the hands and vibrated as the inductor was inserted. The heating and vibration were due to the eddy currents in the core induced by the inductors changing magnetic field.

Test with the Repulsion Coil

The repulsion coil is a ring made from a few turns of No. 28 AWG magnet wire wound with its terminal shorted. The core with the ring on it was positioned in the inductor. The ring was ejected away when the inductor was energized.

CONCLUSION

The dimming of lamps was caused by the current limiting property of inductor. As the lamp combinations resulting resistance becomes low, current flow to increase through them; however the inductor in series opposed or limited the flow as indicated in the result of experimentation.

When it comes to magnetic polarity, AC source has no specific polarity while DC source has a very distinct polarity. The reason is with DC source the flow of current is unidirectional so the poles were distinct. With AC there is a cyclic reversal of the current (60 Hz) so the poles reverse too at this frequency.

Repulsion of the short-circuited coil was due to mutual inductance. It is like a transformer with a short-circuited secondary winding. The coil loosely mounted the core; the coil self inductance produces a magnetic field opposite to that of the magnetic field of the inductor thus the magnetic repulsion.

With these conclusions, simulations on the principles of operation in the following industries are:

- Power Industry
- Metallurgy
- Semi-Conductor Industry
- Rapid Rails Maglev Trains
- Aero-Space Industry (Satellite Catapult)

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