Assessment and Performance Evaluation of Capacitive Property of Inductor and Inductive Property of Capacitor in Linear Circuit

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***Abstract*—Capacitor and inductor are very important circuit components in almost all electrical and electronic applications. They are used as two terminal passive components in electrical circuit. Energy storage, power conditioning, power factor correction, high and low pass filter, noise suppression, starter, oscillators and for many other purposes capacitor is used. Inductors are used extensively with capacitors and resistors to create filters for analog circuits and in signal processing. Alone, an inductor functions as a low-pass filter, since the impedance of an inductor increases as the frequency of a signal increases. For many reasons there may arise a need to exchange a capacitor with an inductor. In this paper we'll discuss about the replacement of a capacitor with an inductor keeping the current and voltage same in the electrical circuit.**

Keywords—Capacitance, Dielectric Inductance, Reactance, Quadratic polynomial

I. INTRODUCTION

A capacitor is a passive electronic component that stores energy in the form of an electrostatic field. In its simplest form, a capacitor consists of two conducting plates separated by an insulating material called the dielectric [1]. The capacitance is directly proportional to the surface areas of the plates, and is inversely proportional to the separation between the plates. Capacitance also depends on the dielectric constant of the substance separating the plates. When there is a potential difference across the conductors (e.g., when a capacitor is attached across a battery), an electric field develops across the dielectric, causing positive charge (+Q) to collect on one plate and negative charge (-Q) to collect on the other plate. If a battery has been attached to a capacitor for a sufficient amount of time, no current can flow through the capacitor [2]. However, if an accelerating or alternating voltage is applied across the leads of the capacitor, a displacement current can flow. Although the capacitance C of a capacitor is the ratio of the charge q per plate to the applied voltage v, it does not depend on q or v. It depends on the physical dimensions of the capacitor. The capacitance can be given by

$$C = \epsilon \frac{A}{d} \tag{1}$$

An Inductor is a passive element designed to store energy in its magnetic field. Inductors find numerous applications in electronic & power systems. Any conductor of electric current has inductive properties and may be regarded as an inductor. But in order to enhance the inductive effect, a particular inductor is usually formed into a cylindrical coil with many turns of conducting wire.

II. SYSTEM MODEL

The voltage current relationship for a capacitor can be obtained as,

$$v = \frac{1}{C}\int_{-\infty}^{t} i dt \tag{2}$$

Or,

$$v = \frac{1}{C}\int_{t_o}^{t} i dt + v(t_o) \tag{3}$$

Where, $v(t_o) = q(t_o)/C$ is the voltage across the capacitor. Equation (3) shows that the capacitor voltage depends on the past history of the capacitor current [3]. So, the capacitor has memory- a property that is often exploited. The instantaneous power delivered to the capacitor is

$$p = vi = Cv\frac{dv}{dt} \tag{4}$$

The current voltage relationship for an inductor can be obtained as

$$i = \frac{1}{L}\int_{-\infty}^{t} v(t) dt \tag{5}$$

Or,

$$i = \frac{1}{L}\int_{t_o}^{t} v(t) dt + i(t_o) \tag{6}$$

Where $i(t_o)$ is the total current for $-\infty<t<\infty$ and $i(-\infty) = 0$. The inductor is designed to store energy in its magnetic field. The power delivered to the inductor is

$$p = vi = \left(L\frac{di}{dt}\right) \tag{7}$$

III. SIMULATION

Simulation has been carried out for replacing a capacitive reactance with another inductive reactance in series with previous inductive reactance. For this technique, we used inductor of 10 mH and capacitor of 10 uF. Three resistance of value 10 ohm were also used to complete the circuit. As a source sinusoidal AC voltage having amplitude 40V and frequency 50 Hz were used.

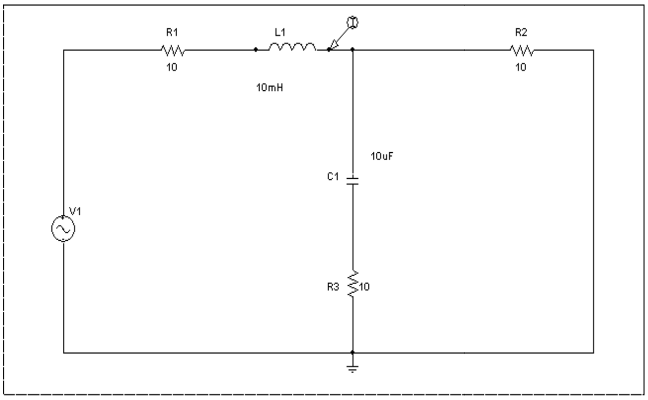

Fig. 1. Capacitor is connected in parallel with Inductor

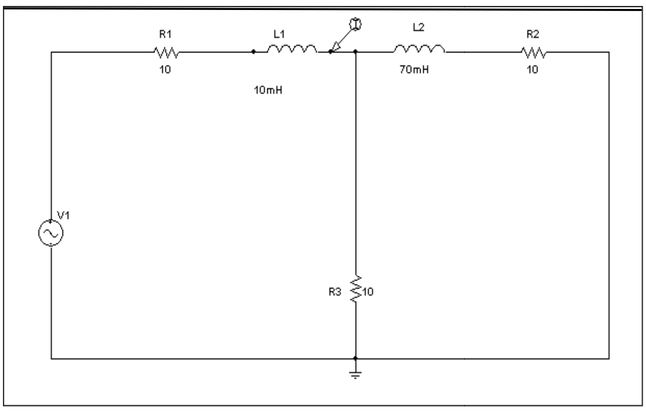

Fig. 2. Capacitor is replaced by a Inducttor in series with previous one

Figure 1 shows the circuit diagram in which capacitor C1 is in parallel with the inductor L1. From this configuration current i_1 is measured. In figure 2, capacitive reactance X_C is replaced by an inductive reactance X_L in series with L1. We also measured the current i_2 for this circuit. We observed that for which value of L2 the current i_1 and i_2 are same.

IV. RESULT AND DISCUSSION

In this paper, we observe the replacement of inductor by capacitor. For various value of capacitive reactance we get various value of inductive reactance when we replaced the capacitor by inductor. All the characteristics of the circuit are same after doing the replacement. We calculate the value of capacitive reactance and inductive reactance from capacitance and inductance by using formula. The relationship between inductance and capacitance can also be found by the proposed method.

TABLE I. Value of inductance for every corresponding value of Capacitance

Capacitance C1 (uF)	Capacitive Reactance X_C (ohm)	Inductance L2 (mH)	Inductive Reactance X_L (ohm)
10	318.3099	70	21.9911
20	159.1549	60	18.8496
30	106.1033	55	17.2788
40	79.5775	52	16.3363
50	63.6620	50	15.7080
60	53.0516	48	15.0796
70	45.4728	44	13.8230
80	39.7887	42	13.1947
90	35.3678	38	11.9381
100	31.8310	35	10.9956
110	28.9373	32	10.0531
120	26.5258	30	9.4248

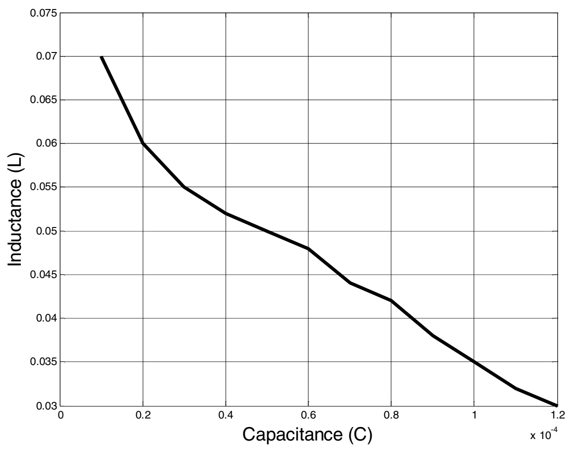

Fig. 3. Relationship between Inductance (L2) and Capacitance(C1)

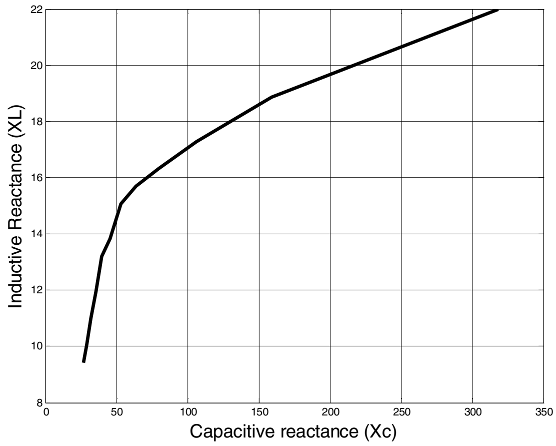

Fig. 4. Graph showing the relationship between Inductive reactance vs Capacitive reactance

From the above figure 4, a relationship between inductive and capacitive reactance has been established. It is clear that the curve follows an equation of quadratic polynomial. For all values of capacitance and inductance the X_L and X_C follow this equation. By considering this polynomial equation we can replace a capacitor by an inductor.

V. Analytical Approach

The exponential voltage for a capacitor can be derived as

$$V(t) = V_o e^{-\frac{t}{\tau}} \tag{8}$$

Where, τ is the time constant. V_o is the initial voltage. The above equation has a slope (rate of change) which is proportional to the value of the function [4, 5]. As the voltage starts from a lower value and then rises to its asymptotic value, an additional constant term is needed in the equation (8).

$$V(t) = V_o(1 - e^{-\frac{t}{\tau}}) \tag{9}$$

In this paper we established a quadratic polynomial equation on the basis of relationship between capacitive and inductive reactance. The polynomial equation is

$$y = ax^2 + bx + c \tag{10}$$

By our observation the polynomial equation can be written as

$$X_L = aX_C^2 + bX_C + c \tag{11}$$

Analyzing the equation with the values of X_L and X_C we can find out the constants a, b and c. As a result we get a new equation of relationship between X_L and X_C

$$X_L = -0.0002X_C^2 + 0.1086X_C + 8.3842 \tag{12}$$

VI. Conclusion

This paper presents a method for establishing a relationship between capacitive and inductive reactance. This relation follows a quadratic polynomial equation which may be helpful for replacement. Where the capacitor is not suitable for an electrical circuit, an inductor can be used by maintaining this equation. The proposed technique is flexible due to its inherent analog nature. The replacement of an inductor by a capacitor can be considered as a future work by this technique.

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