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Analysis of Electric Network Circuits with Sinusoidal Potential Sources via Rohit Transform

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ABSTRACT: The analysis of electric network circuits is an essential course for electrical and electronics engineering. The response of such networks is generally obtained by the different mathematical approaches like Laplace Transform, convolution theorem approach, calculus approach, residue theorem approach. This paper presents a new integral transform called Rohit Transform for obtaining the complete response of the series RL and RC networks with a source of sinusoidal potential. The response obtained will provide electric current (or electric charge) which flows in the series RL and RC networks with a source of sinusoidal potential. In this paper, the response of the series RL and RC network circuits is provided as a demonstration of the application of the new integral transform called Rohit Transform.

KEYWORDS: Rohit Transform; Current; Series RL and RC Networks; Response.

I. INTRODUCTION

The electric circuit of the series RL network consists of two passive electric elements: an inductor Ł and a resistor R, connected in series with a source of sinusoidal potential and the electric circuit of the series RC network consists of two passive electric elements: a capacitor C and a resistor R, connected in series with a source of sinusoidal potential. Such networks are used as a tuning or resonant circuit in the radio and television sets to resonate a particular frequency band from the wide range of radio frequency components, or in the chokes of luminescent tubes [1-4]. The Rohit Transform has been proposed by the author Rohit Gupta in recent years and generally, it has been applied in different areas of science and engineering [5, 6, 7]. The response of electrical networks is generally obtained by the different mathematical approaches like the calculus approach [1-3], residue theorem approach [8], convolution theorem approach [9], and by various integral transforms like Laplace Transform [1-3], Mohand Transform [10, 11], Aboodh Transform [12], Elzaki Transform [13], Gupta Transform [14]. This paper presents the use of a new integral transform called Rohit Transform for obtaining the complete response of the series RL and RC networks with a source of sinusoidal potential.

Basics of Rohit Transform

The Rohit Transform [5, 15] of g(y), y ≥ 0 is defined as $R\{g(y)\} = r^3\int_0^\infty e^{-ry}\, g(y)dy = G(r)$, provided that the integral is convergent, where r may be a real or complex parameter. The Rohit Transform of some derivatives [6, 7, 15] of g(y) is given by

$R\,\{g'(y)\} = rR\{g(y)\} - r^3 g(0)$

Or

$R\,\{g'(y)\} = rG(r) - r^3 g(0),$

$R\{g''(y)\} = r^2 G(r) - r^4 g(0) - r^3 g'(0),$

And so on.

II. MATERIAL AND METHOD

A. SERIES RL NETWORK CIRCUIT WITH SINUSOIDAL POTENTIAL SOURCE

We will take a series RL network to which a sinusoidal voltage source of potential $V_0 \sin \omega t$ is applied through a key K as shown in figure 1.

As the switch is closed at t = 0, the potential drops across the network elements [1-4] are given by

$V_R\,(t) = I(t)R,\; V_L\,(t) = ŁĐ_t[I(t)].$

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Therefore, the application of Kirchhoff's loop law to the loop shown in figure 2 provides

$V_R(t) + V_{\text{Ł}}(t) = V$

Or

$\text{Ɽ}\, I(t) + \text{Ł}\text{Đ}_t[I(t)] = V_0 \sin \omega t$….. (1) $\text{Đ}_t \equiv \frac{d}{dt}$.

Differentiating (1), we get a differential equation of order 2 as given below:

$\text{Đ}_t^2[I(t)] + \frac{R}{\text{Ł}}\text{Đ}_t[I(t)] = \frac{V_0\omega}{\text{Ł}} \cos \omega t$ …. (2)

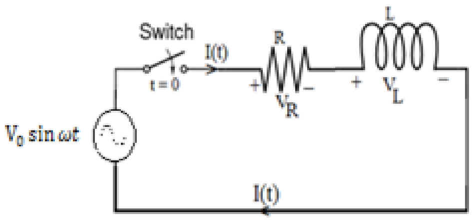

Figure 1: Series LR network with sinusoidal voltage source.

To solve equation (2), we first write the initial conditions as follows [1-4]:

- Since the current in the inductor and the electric potential difference across the capacitor cannot change instantaneously, therefore, as the switch is closed at the instant t = 0, then I (0) = 0.
- Since I (0) = 0, therefore, (1) provides $\text{Đ}_t[I(0)] = 0$.

The Rohit Transform [5, 6, 7, 15] of (2) provides

$q^2\bar{I}(q) - q^4 I(0) - q^3 D_t[I(0)] + \frac{R}{\text{Ł}}\{q\bar{I}(q) - q^3 I(0)\} = \frac{V_0\omega}{\text{Ł}} \frac{q^4}{q^2+\omega^2}$ ……. (3)

Applying $I(0) = 0$ and $[I'(0)] = 0$, (3) becomes

$q^2\bar{I}(q) + \frac{R}{\text{Ł}} q\bar{I}(q) = \frac{V_0\omega}{\text{Ł}} \frac{q^4}{q^2+\omega^2}$

Or

$\bar{I}(q) = \frac{V_0}{\text{Ł}} \frac{\omega q^3}{q^2+\omega^2}\left[\frac{1}{q+\frac{R}{\text{Ł}}}\right]$

This equation can be re written as

$\bar{I}(q) = \frac{V_0}{\text{Ł}}\left\{\left[\frac{\text{Ł}}{(\omega\text{Ł})^2+R^2}\left(R\frac{\omega q^3}{q^2+\omega^2} - \omega\text{Ł}\frac{q^4}{q^2+\omega^2}\right)\right] + \left[\frac{\omega\text{Ł}^2}{(\omega\text{Ł})^2+R^2}\frac{q^3}{q+\frac{R}{\text{Ł}}}\right]\right\}$

Taking inverse Rohit Transform [5], we have

$I(t) = \frac{V_0}{\text{Ł}}\left\{\left[\frac{\text{Ł}}{(\omega\text{Ł})^2+R^2}(R\sin \omega t - \omega\text{Ł}\cos \omega t)\right] + \left[\frac{\omega\text{Ł}^2}{(\omega\text{Ł})^2+R^2} e^{-\left(\frac{R}{\text{Ł}}\right)t}\right]\right\}$

Or

$I(t) = \frac{V_0}{\sqrt{(\omega\text{Ł})^2+R^2}}\left\{\left[\left(\frac{R}{\sqrt{(\omega\text{Ł})^2+R^2}}\sin \omega t - \frac{\omega\text{Ł}}{\sqrt{(\omega\text{Ł})^2+R^2}}\cos \omega t\right)\right] + \left[\frac{\omega\text{Ł}}{\sqrt{(\omega\text{Ł})^2+R^2}} e^{-\left(\frac{R}{\text{Ł}}\right)t}\right]\right\}$…….. (4)

Put $\frac{\omega\text{Ł}}{\sqrt{(\omega\text{Ł})^2+R^2}} = \sin \emptyset$ and $\frac{R}{\sqrt{(\omega\text{Ł})^2+R^2}} = \cos \emptyset$ such thattan $\emptyset = \frac{\omega\text{Ł}}{R}$, then we can rewrite equation (4) as

$I(t) = \frac{V_0}{\sqrt{(\omega\text{Ł})^2+R^2}}\left\{[(\cos \emptyset \sin \omega t - \sin \emptyset \cos \omega t)] + \left[\sin \emptyset\, e^{-\left(\frac{R}{\text{Ł}}\right)t}\right]\right\}$

Or

$I(t) = \frac{V_0}{\sqrt{(\omega\text{Ł})^2+R^2}}\left\{\sin(\omega t - \emptyset) + \sin \emptyset\, e^{-\left(\frac{R}{\text{Ł}}\right)t}\right\}$….. (5)

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This equation (5) provides the complete response of the series Ł − R network with a source of sinusoidal potential.

B. SERIES RC NETWORK CIRCUIT WITH SINUSOIDAL POTENTIAL SOURCE

The series R-C network circuit with a sinusoidal potential source (as shown in figure 2) [1-3] is analyzed by the following equation

$$\dot{Q}(t)R + \frac{Q(t)}{C} = V_0 \sin \omega t$$

Or

$$\dot{Q}(t) + \frac{1}{RC} Q(t) = \frac{V_0}{R} \sin \omega t \quad \ldots..(6)$$

Here, $Q(t)$ is the instantaneous charge and Q (0) = 0.

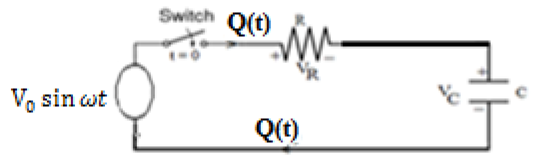

Figure 2: SERIES RC NETWORK CIRCUIT WITH SINUSOIDAL POTENTIAL SOURCE

The Rohit Transform [5, 6, 7,] of (6) gives

$$\{q\bar{Q}(q) - q^3 Q(0)\} + \frac{1}{RC}\bar{Q}(q) = \frac{V_0}{R}\frac{\omega q^3}{q^2+\omega^2}$$

Put Q (0) = 0 we get

$$\{q\bar{Q}(q)\} + \frac{1}{RC}\bar{Q}(q) = \frac{V_0}{R}\frac{\omega q^3}{q^2+\omega^2}$$

$$\bar{Q}(q) = \frac{V_0}{R}\frac{\omega q^3}{(q^2+\omega^2)(q+\frac{1}{RC})}$$

$$\bar{Q}(q) = \frac{V_0}{R}\left\{\left[\frac{RC}{(\omega RC)^2+1}\left(\frac{\omega q^3}{q^2+\omega^2} - \omega RC\frac{q^4}{q^2+\omega^2}\right)\right] + \left[\frac{\omega(CR)^2}{(\omega RC)^2+1}\frac{q^3}{q+\frac{1}{RC}}\right]\right\}$$

Taking inverse Rohit Transform [5], we have

$$Q(t) = \frac{V_0}{R}\left\{\left[\frac{RC}{(\omega RC)^2+1}(\sin \omega t - \omega RC \cos \omega t)\right] + \left[\frac{\omega(CR)^2}{(\omega RC)^2+1}e^{-\left(\frac{1}{RC}\right)t}\right]\right\}$$

Or

$$Q(t) = \frac{V_0}{\sqrt{(\omega RC)^2+1}}\left\{\left[\left(\frac{C}{\sqrt{(\omega RC)^2+1}}\sin \omega t - \frac{\omega RC^2}{\sqrt{(\omega RC)^2+1}}\cos \omega t\right)\right] + \left[\frac{\omega RC^2}{\sqrt{(\omega RC)^2+1}}e^{-\left(\frac{1}{RC}\right)t}\right]\right\} \ldots\ldots.. (7)$$

Put $\frac{\omega RC^2}{\sqrt{(\omega RC)^2+1}} = \sin \emptyset$ and $\frac{C}{\sqrt{(\omega RC)^2+1}} = \cos \emptyset$ such that $\tan \emptyset = \omega RC$, then we can rewrite equation (7) as

$$I(t) = \frac{V_0}{\sqrt{(\omega RC)^2+1}}\left\{[(\cos \emptyset \sin \omega t - \sin \emptyset \cos \omega t)] + \left[\sin \emptyset\, e^{-\left(\frac{1}{RC}\right)t}\right]\right\}$$

Or

$$Q(t) = \frac{V_0}{\sqrt{(\omega RC)^2+1}}\left\{\sin(\omega t - \emptyset) + \sin \emptyset\, e^{-\left(\frac{1}{RC}\right)t}\right\} \ldots. (8)$$

This equation (8) provides the complete response of the series RC network with a source of sinusoidal potential.

III. CONCLUSION

In this paper, a new integral transform called Rohit Transform has successfully applied for determining the complete response (electric current) of a series RL and RC networks with a source of sinusoidal potential. The results obtained are the same as obtained with other approaches [1-4]. This approach brings up the Rohit Transform as a new and powerful tool for determining the response of network circuits.

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