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ANALYSIS OF RLC CIRCUITS WITH EXPONENTIAL EXCITATION SOURCES BY A NEW INTEGRAL TRANSFORM: ROHIT TRANSFORM

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ABSTRACT

In science and engineering, the analysis of RLC network circuits is a principal course and is generally done by applying calculus or Laplace Transform. In this paper, we will analyze RLC network circuits with exponential excitation sources by applying a new integral transform: Rohit Transform and obtained their responses in the form of current or voltage. This paper presents the use of the Rohit Transform and proves its applicability for analyzing the RLC network circuits with exponential excitation sources and concludes that Rohit Transform like other transforms or approaches is also an effective and simple tool.

Index Terms- Rohit Transform; Network Circuits; Exponential Excitation Source; Response

I. INTRODUCTION

The RLC network circuits are generally analyzed by applying calculus [1-2] or Laplace Transform [3] and their response depends on inductance L, capacitance C, and resistance R. Such network circuits are mostly used as a tuning or resonant circuit or in oscillatory circuits [4, 5]. In this paper, a new integral transform named Rohit Transform is presented to analyze the RLC network circuits with exponential excitation sources. This Transform has been put forward by the author Rohit Gupta in recent years and so this transform is not widely known. The Rohit Transform has been applied in science and engineering to solve most of the boundary value problems [6]. This paper presents the use and applicability of Rohit Transform for analyzing the network circuits with exponential excitation sources and concludes that Rohit Transform like other methods or approaches is an effective and simple tool for analyzing the RLC network circuits with exponential sources.

II. BASIC DEFINITION

2.1 Rohit Transform

The Rohit Transform (RT) [6] of g(y), denoted by $R\{g(y)\}$, is defined as

$R\{g(y)\} = r^3 \int_0^\infty e^{-ry} g(y)\,dy$, provided that the integral is convergent, where r may be a real or complex parameter. The Rohit Transform of some of the derivatives of a function is

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

$R\{g''(y)\} = r^2 R\{g(y)\} - r^4 g(0) - r^3 g'(0)$ and so on.

III. MATERIAL AND METHOD

Analysis of a series RLC circuit with an exponential potential source

The differential equation for a **series RLC circuit with exponential potential source [4, 7]**, shown in figure (1), is given by

$I(t)R + L\dot{I}(t) + \frac{Q(t)}{C} = ve^{-ut}$.... (1)

Differentiating (1) w.r.t. t and simplifying we get,

$\ddot{I}(t) + \frac{R}{L}\dot{I}(t) + \frac{1}{LC}I(t) = \frac{-vu}{L}e^{-ut}$ .... (2)

Here, $I(t)$ is the instantaneous current in the circuit.

The initial conditions [7], [9], [10] are

(i) $I(t = 0) = 0$..... (3)

(ii) Since $I(t = 0) = 0$, therefore, equation (1) gives $\dot{I}(t = 0) = \frac{v}{L}$...... (4)

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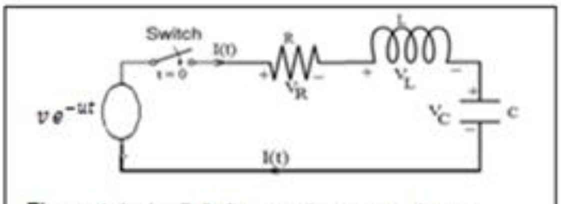

Figure 1: Series R-L-C network connected to an excitation source of exponential potential.

Taking the Rohit transform [6] of equation (2), we get

$$q^2\bar{I}(q) - q^4 I(0) - q^3\dot{I}(0) + \frac{R}{L}\{q\bar{I}(q) - q^3 I(0)\} + \frac{1}{LC}\bar{I}(q) = \frac{-vuq^3}{L(q+u)}$$

... (5)

Applying conditions: $I(0) = 0$ and $\dot{I}(0) = \frac{v}{L}$ and simplifying (5), we get

$$\bar{I}(q) = \frac{v}{L}\frac{q^4}{(q+u)(q^2+\frac{R}{L}q+\frac{1}{LC})} \text{..... (6), } where\ 2\delta = \frac{R}{L}\ and\ \omega = \sqrt{\frac{1}{LC}}$$

or

$$\bar{I}(q) = \frac{v}{L}\frac{q^4}{(q+u)(q^2+\ 2\,\delta\, q+\omega^2)}$$

or

$$\bar{I}(q) = \frac{v}{L}\frac{q^4}{(q+u)(q+\beta_1)(q+\beta_2)} \text{.... (7)}$$

where $\omega' = \sqrt{\delta^2-\omega^2}, \delta+\omega' = \beta_1$ *and* $\delta-\omega' = \beta_2,\ \beta_1-\beta_2 = 2\omega'$

.

Therefore,

$$\bar{I}(q) = \frac{v}{L}\left\{\frac{-uq^3}{(q+u)(-u+\beta_1)(-u+\beta_2)} + \frac{-\beta_1 q^3}{(-\beta_1+u)(q+\beta_1)(-\beta_1+\beta_2)} + \frac{-\beta_2 q^3}{(-\beta_2+u)(-\beta_2+\beta_1)(q+\beta_2)}\right\} \text{...... (8)}$$

Applying inverse Rohit Transform [6], we get

$$I(t) = \frac{v}{L}\left\{\frac{-ue^{-ut}}{(-u+\beta_1)(-u+\beta_2)} + \frac{-\beta_1 e^{-\beta_1 t}}{(-\beta_1+u)(-\beta_1+\beta_2)} + \frac{-\beta_2 e^{-\beta_2 t}}{(-\beta_2+u)(-\beta_2+\beta_1)}\right\}$$

or

$$I(t) = \frac{v}{L}\left\{\frac{[\delta-\omega']e^{-\delta t}e^{\omega' t}}{2\omega'[\delta-\omega'-u]} - \frac{ue^{-ut}}{[\delta+\omega'-u][\delta-\omega'-u]} - \frac{[\delta+\omega']e^{-\delta t}e^{-\omega' t}}{2\omega'[\delta+\omega'-u]}\right\} \text{... (9)}$$

This equation (9) gives the response (current) of a series R-L-C circuit with an exponential potential source at any instant.

When t increases indefinitely, $e^{-\delta t}$ tends to zero, so

$$I(t) = \frac{v}{L}\frac{-ue^{-ut}}{[\delta+\ \omega'-u][\delta-\ \omega'-u]}$$

or

$$I(t) = \frac{v}{L}\frac{ue^{-ut}}{[u^2-\omega^2-2\,\omega']}$$

Analysis of a parallel RLC circuit with exponential current source

The differential equation for a **parallel RLC circuit with an exponential current source [5, 8],** shown in figure (2), is given by

$$\frac{V(t)}{R} + \frac{1}{L}\int V(t)\,dt + C\,\dot{V}(t) = I_0 e^{-ut} \text{..... (10)}$$

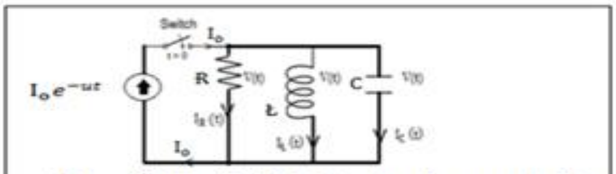

Figure 2: Parallel R-L-C network connected to an exponential excitation current source

Differentiate (10) w.r.t. t and simplifying, we get,

$$\ddot{V}(t) + \frac{1}{RC}\dot{V}(t) + \frac{1}{LC}V(t) = \frac{-I_0 u}{C}e^{-ut} \text{ .... (11)}$$

The initial conditions [8], [9],[10] are

(i) $V(t=0) = 0.$

(ii) Since $V(0) = 0$, therefore, (11) gives $\dot{V}(0) = \frac{I_0}{C}$.

Taking Rohit Transform [6] of (11), we get

$$q^2\bar{V}(q) - q^4V(0) - q^3\dot{V}(0) + \frac{1}{RC}\{q\bar{V}(q) - q^3V(0)\} + \frac{1}{LC}\bar{V}(q) = \frac{-I_0\,uq^3}{C(q+u)}$$

.... (12)

Applying conditions: $V(0) = 0$ and $\dot{V}(0) = \frac{I_0}{C}$ and simplifying (12), we get

$$\bar{V}(q) = \frac{I_0}{C}\left[\frac{q^4}{(q+u)(q^2+\ 2\,a\,q+\omega^2)}\right], where\ 2a = \frac{1}{RC}\ and\ \omega = \frac{1}{LC}$$

or

$$\bar{V}(q) = \frac{I_0}{C}\left[\frac{q^4}{(q+u)(q+a_1)(q+a_2)}\right]$$

where $a+\omega' = a_1$ *and* $a-\omega' = a_2, \omega' = \sqrt{a^2-\omega^2},\ a_1-a_2 = 2\omega'$

Therefore,

$$\bar{V}(q) = \frac{I_0}{C}\left\{\frac{-uq^2}{(q+u)(-u+a_1)(-u+a_2)} + \frac{-a_1q^2}{(-a_1+u)(q+a_1)(-a_1+a_2)} + \frac{-a_2q^2}{(-a_2+u)(-a_2+a_1)(q+a_2)}\right\}$$

Applying inverse Rohit Transform [6], we get

$$V(t) = \frac{I_0}{C}\left\{\frac{-ue^{-ut}}{(-u+\beta_1)(-u+\beta_2)} + \frac{-\beta_1 e^{-\beta_1 t}}{(-\beta_1+u)(-\beta_1+\beta_2)} + \frac{-\beta_2 e^{-\beta_2 t}}{(-\beta_2+u)(-\beta_2+\beta_1)}\right\}$$

or

$$V(t) = \frac{I_0}{C}\left\{\frac{[\delta-\omega]e^{-\delta t}e^{\omega' t}}{2\omega'[\delta-\omega'-u]} - \frac{ue^{-ut}}{[\delta+\omega'-u][+\delta-\omega'-u]} - \frac{[\delta+\omega]e^{-\delta t}e^{-\omega' t}}{2\omega'[\delta+\omega'-u]}\right\}$$

.... (13)

This equation (13) gives the response (potential) of a parallel R-L-C circuit with an exponential current source at any instant.

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When t increases indefinitely, $e^{-\delta t}$ tends to zero, so

$$V(t) = \frac{I_0}{C} \frac{-ue^{-ut}}{[\delta + \omega' - u][\delta - \omega' - u]}$$

or

$$V(t) = \frac{I_0}{C} \frac{ue^{-ut}}{[u^2 - \omega^2 - 2\,\omega']}$$

IV. RESULT AND CONCLUSION

In this paper, we have successfully obtained the response of RLC circuits with exponential sources. This paper exemplified the application of Rohit Transform for obtaining the response of RLC circuits with exponential sources. This paper brought up the Rohit Transform like other integral transforms, as a simple and effective technique for analyzing the RLC circuits with exponential sources. The results obtained are the same as obtained with other methods or approaches.

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