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ON NOTEWORTHY APPLICATIONS OF DINESH VERMA TRANSFORM

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Abstract: An electrical inverter presents the function of converting DC voltage (or power) into AC voltage (or power) at the aspiration frequency. This paper make obvious the application of the Dinesh Verma Transform for examine the basic series inverter.The study of basic series inverter by submit an application Dinesh Verma Transform gives the answer (electric current) of the basic series inverter which is usually geted by calculus and analytic methods. In this paper, the answer of a basic series inverter is geted as a demonstration of the application of the Dinesh Verma Transform (DVT).
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***Index Terms*:** Dinesh Verma Transform (RT), Basic Series Inverter, Response.

INTRODUCTION

The Dinesh Verma Transform (DVT) applied in different areas of science, engineering and technology [1], [2], [3] [4], [5], [6], [7] [8,9,10,11,12,13] The Dinesh Verma Transform (DVT) is implemented in various fields and fruitfully solving linear differential equations. Via Dinesh Verma Transform (DVT) Ordinary linear differential equation with constant coefficient and variable coefficient and simultaneous differential equations can be easily resolved, without finding their complementary solutions. It also comes out to be very effective tool to analyze differential equations[14,15,16,17,18,19,20], Simultaneous differential equations, Integral equations etc. The electrical circuit performs the function of converting DC voltage (or power) into AC voltage (or power) at the desired frequency, is an inverter. In a series inverter (shown in figure 1) commutating elements Ł and C are attached unendingly in series with the load resistor R.The thyristors T_1 and T_2 are alternately rotated on.[21,22,23,24,25,26,27] The values of commutating elements Ł and C in series with load resistor R are such that the Ł-C- R network forms an underdamped circuit. An Inverter is used in the domestic installations and in the commercial installations as a source of stand by electric supply, in industrial installations for induction heating and for a variable speed AC drives [1-4].The 'Dinesh Verma Transform (RT)' was projected by 'Dinesh Verma' in the year 2020 and applied for analyzing boundary value problems described by linear ordinary differential equations in Science and Engineering [5]. This paper demonstrates the application of the Dinesh Verma Transform for analyzing the basic series inverter to obtain itsresponse (electric current).

DINESH VERMA TRANSFORM (DVT)

Let g(y) is a well-defined function of real numbers y ≥ 0. The Dinesh Verma Transform [5] of g(y), denoted by $G(r)$ or $D\{g(y)\}$, is defined as $D\{g(y)\} = r^3 \int_0^\infty e^{-ry} g(y)dy = G(r)$, provided that the integral is convergent, where r may be a real or complex parameter and R is the Dinesh Verma Transform operator.

The Dinesh Verma Transform of some of the derivatives of a function is

$$D\{f'(t)\} = p\bar{f}(p) - p^5 f(0)$$
$$D\{f''(t)\} = p^2\bar{f}(p) - p^6 f(0) - p^5 f'(0)$$
$$D\{f'''(y)\} = p^3\bar{f}(p) - p^7 f(0) - p^6 f'(0) - p^5 f''(0)$$ And so on.

$$D\{tf(t)\} = \frac{5}{p}\bar{f}(p) - \frac{d\bar{f}(p)}{dp},$$

$$D\{tf'(t)\} = \frac{5}{p}\left[p\bar{f}(p) - p^5 f(0)\right] - \frac{d}{dp}\left[p\bar{f}(p) - p^5 f(0)\right]$$ and

$$D\{tf''(t)\} = \frac{5}{p}[p^2\bar{x}(p) - p^6 x(0) - p^5 x'(0)] - \frac{d}{dp}[p^2\bar{x}(p) - p^6 x(0) - p^5 x'(0)]$$ And so on.

DINESH VERMA TRANSFORM OF ELEMENTARY FUNCTIONS

According to the definition of Dinesh Verma transform (DVT),

$$\mathrm{D}\{t^n\} = p^5 \int_0^\infty e^{-pt}\, t^n dt$$
$$= p^5 \int_0^\infty e^{-z} \left(\frac{z}{p}\right)^n \frac{dz}{p} \quad ,z = pt$$
$$= \frac{p^5}{p^{n+1}} \int_0^\infty e^{-z}\,(z)^n dz$$

Applying the definition of gamma function,

$$\mathrm{D}\,\{y^n\} = \frac{p^5}{p^{n+1}} \Gamma(n+1)$$
$$= \frac{1}{p^{n-4}} n!$$
$$= \frac{n!}{p^{n-4}}$$

Hence, $D\{t^n\} = \frac{n!}{p^{n-4}}$

DVT of some elementary Functions

- $D\{t^n\} = \frac{n!}{p^{n-4}}$, $where\ n = 0,1,2,..$
- $D\{e^{at}\} = \frac{p^5}{p-a}$,
- $D\{sinat\} = \frac{ap^5}{p^2+a^2}$,
- $D\{cosat\} = \frac{p^6}{p^2+a^2}$,
- $D\{sinhat\} = \frac{ap^5}{p^2-a^2}$,
- $D\{coshat\} = \frac{p^6}{p^2-a^2}$.
- $D\{\delta(t)\} = p^4$

- The Inverse Dinesh Verma Transform (DVT) of some of the functions are given by
- $D^{-1}\left\{\frac{1}{p^{n-4}}\right\} = \frac{t^n}{n!}$, $where\ n = 0,1,2,..$
- $D^{-1}\left\{\frac{p^5}{p-a}\right\} = e^{at}$,
- $D^{-1}\left\{\frac{p^5}{p^2+a^2}\right\} = \frac{sinat}{a}$,
- $D^{-1}\left\{\frac{p^6}{p^2+a^2}\right\} = cosat$,
- $D^{-1}\left\{\frac{p^5}{p^2-a^2}\right\} = \frac{sinhat}{a}$,
- $D^{-1}\left\{\frac{p^6}{p^2-a^2}\right\} = coshat$,
- $D^{-1}\{p^4\} = \delta(t)$

METHODOLOGY

Considering a basicε series inverter [1-4] as given in figure 1. We are analyzing the basic series inverter in three modes of operations.

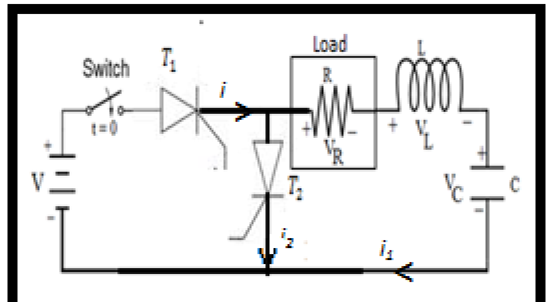

Figure 1: Basic Series Inverter

In the first mode of operation of the basic series inverter, since the thyristor T_2 is off and the thyristor T_1 is on, therefore, the equivalent circuit, in this case, is given in figure 2.

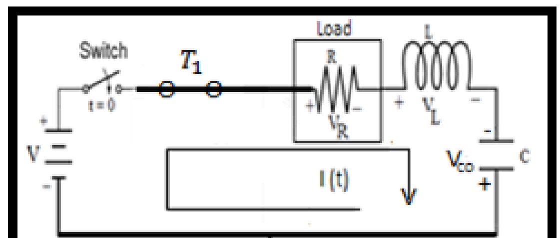

Figure 2: Equivalent Circuit (T_2 is OFF and T_1 is ON)

In this mode of operation, the capacitor is considered to be initially charged to a potential V_{CO} , with the upper plate which have negative polarity and the lower plate having positive polarity [1-4].Therefore, at t = 0+,the application of Kirchhoff's loop law provides

R I(t)+ Ł[I′(t)] + $\frac{q(t)}{C}$ = V +V_{CO} ... (I)

Differentiate equation (1) and simplifying, we get

$[I''(t)]$ + $\frac{R}{Ł}$[I′(t)] + $\frac{1}{ŁC}$I(t) = 0 …. (II)

HereI$(t = [q'(t)]$ is the instantaneous electric current flowing in the series Ł - C- R network circuit.

The relevant boundary conditions[6-7] are as follows:

At the instant t = 0, I (0) = 0.

Since I (0) = 0, therefore, equation (I) provides[I′(0)] = $\frac{V + V_{CO}}{Ł}$.

The Dinesh Verma Transform of equation (II) provides

$r^2\bar{I}(r) - r^6 I(0) - r^5 D_t[I(0)]$ +

$\frac{R}{Ł}\{r\,\bar{I}(q) - r^5 I(0)\} + \frac{1}{ŁC}\bar{I}(r) = 0$...... (III)

Applying boundary conditions: I(0) =0 and

[I′(0)] = $\frac{V + V_{CO}}{Ł}$, equation (III) becomes,

$r^2\bar{I}(r) - \frac{V + V_{CO}}{Ł} r^5 + \frac{R}{Ł} r\,\bar{I}(r) + \frac{1}{ŁC}\bar{I}(r) = 0$

Or

$\bar{I}(r)\,[r^2 + \frac{R}{Ł}r + \frac{1}{ŁC}] = \frac{V + V_{CO}}{Ł}\, r^5$

Or

$$\bar{I}(r) = \frac{V + V_{CO}}{Ł}\left[\frac{r^5}{r^2 + \frac{R}{Ł}r + \frac{1}{ŁC}}\right]$$

Or

$$\bar{I}(r) = \frac{V + V_{CO}}{Ł}\left[\frac{r^5}{\left(r+\frac{R}{2Ł}\right)^2 + [\frac{1}{ŁC} - \left(\frac{R}{2Ł}\right)^2]}\right] \text{.......... (IV)}$$

According to the condition [8-9] for the circuit to be underdamped, $\frac{1}{ŁC} > \left(\frac{R}{2Ł}\right)^2$ or $\frac{1}{ŁC} - \left(\frac{R}{2Ł}\right)^2 > 0$, therefore on putting $\frac{1}{ŁC} - \left(\frac{R}{2Ł}\right)^2 = \varepsilon^2$ or $\varepsilon = \sqrt{\frac{1}{ŁC} - \left(\frac{R}{2Ł}\right)^2}$ in equation (4), we can rewrite equation (4) as

$$\bar{I}(r) = \frac{V + V_{CO}}{Ł}\left[\frac{r^5}{\left(r+\frac{R}{2Ł}\right)^2 + \varepsilon^2}\right]$$

Or

$$\bar{I}(r) = \frac{V + V_{CO}}{Ł}\left[\frac{r^5}{\left(r + \frac{R}{2Ł} - i\varepsilon\right)\left(r + \frac{R}{2Ł} + i\varepsilon\right)}\right]$$

Or

$\bar{I}(r) = \frac{V + V_{CO}}{Ł}\left[\frac{r^5}{(r+a)(r+c)}\right]$, where $a = \frac{R}{2Ł} - i\varepsilon$ and $c = \frac{R}{2Ł} + i\varepsilon$ such that $a - c = -2i\varepsilon$.

Or

$$\bar{I}(r) = \frac{V + V_{CO}}{Ł}\left[\frac{r^5}{(r+a)(r+c)}\right]$$

Or

$$\bar{I}(r) = \frac{V + V_{CO}}{Ł(a-c)}\left[\frac{r^5}{(r+c)} - \frac{r^5}{(r+a)}\right] \text{..... (V)}$$

The inverse DVT of equation (5) provides

$$I(t) = \frac{V + V_{CO}}{-2i\varepsilon Ł}\,[e^{-ct} - e^{-at}]$$

Or

$$I(t) = \frac{V + V_{CO}}{2i\omega Ł}\,[e^{i\varepsilon t} - e^{-i\varepsilon t}]$$

Or

$$I(t) = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-\frac{R}{2Ł}t} \sin \varepsilon t$$

Or

$$I(t) = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-\frac{R}{2Ł}t} \sin \varepsilon t \text{ .... (VI)}$$

This equation (6) confirms that the current I(t) is sinusoidal in nature with exponentially decreasing amplitude. At $t = \frac{\pi}{\varepsilon}$, $I(\frac{\pi}{\varepsilon}) = 0$ i.e. at the instant $t = \frac{\pi}{\varepsilon}$, the current in the circuit becomes zero. To find the voltage drop across the inductor, differentiating equation (VI) w.r.t. t, we get

$$[I'(t)] = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-\frac{R}{2Ł}t}\,[\varepsilon \cos \omega t - \frac{R}{2Ł}\sin \varepsilon t] \text{ .. (VII)}$$

For simplifying equation (VII), let us put $\frac{R}{2Ł} = b$, where b is known as damping constant, and $\frac{1}{ŁC} = \varepsilon_o^2$, where ε_o is known as resonant frequency such that $\varepsilon = \sqrt{\varepsilon_o^2 - b^2}$ or $\omega_o = \sqrt{\varepsilon^2 + b^2}$, then we can rewrite equation (VII) as

$$[I'(t)] = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-bt}\,[\varepsilon \cos \varepsilon t - b \sin \varepsilon t]$$

Or

$$[I'(t)] = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-bt}\varepsilon_o[\frac{\varepsilon}{\varepsilon_o}\cos \omega t - \frac{b}{\varepsilon_o}\sin \varepsilon t] \text{... (VIII)}$$

Put $\frac{\varepsilon}{\varepsilon_o} = \cos\alpha$ and $\frac{b}{\omega_o} = \sin\alpha$ such that $\alpha = \tan^{-1}\frac{b}{\varepsilon}$, equation (VIII) becomes

$$[I'(t)] = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-bt}\varepsilon_o[\cos\alpha \cos \varepsilon t - \sin\alpha \sin \varepsilon t]$$

Or

$$[I'(t)] = \frac{V + V_{CO}}{\varepsilon Ł}\, e^{-bt}\varepsilon_o \cos(\varepsilon t + \alpha) \text{ .... (IX)}$$

The voltage drop across the inductor [VI] is given by

$$V_Ł(t) = Ł[I'(t)]$$

Or

$$V_Ł(t) = \frac{V + V_{CO}}{\varepsilon}\, e^{-bt}\varepsilon_o \cos(\varepsilon t + \alpha) \text{ ... (X)}$$

We can determine the voltage across capacitor as

$$V_R(t) + V_Ł(t) + V_C(t) = V$$

Or

$$V_C(t) = V - V_R(t) - V_Ł(t)$$

Or

$$V_C(t) = V - R\,I(t) - V_Ł(t) \text{ ...... (XI)}$$

Using equations (VI) and (X) in equation (XI) and simplifying, we get

$$V_C(t) = V - \frac{V + V_{CO}}{\varepsilon}\, e^{-bt}\varepsilon_o \cos(\varepsilon t - \alpha) \text{.. (XII)}$$

At $t = \frac{\pi}{\varepsilon}$,

$$V_C\left(\frac{\pi}{\varepsilon}\right) = V - \frac{V + V_{CO}}{\varepsilon}\, e^{-b\frac{\pi}{\varepsilon}}\varepsilon_o \cos(\pi - \alpha)$$

Or

$$V_C\left(\frac{\pi}{\varepsilon}\right) = V + \frac{V + V_{CO}}{\varepsilon}\, e^{-b\frac{\pi}{\varepsilon}}\varepsilon_o \cos(\alpha) \text{.... (XIII)}$$

As $\frac{\epsilon}{\varepsilon_o} = \cos\alpha$, equation (XIII) becomes

Or

$$V_C\left(\frac{\pi}{\varepsilon}\right) = V + (V + V_{CO})e^{-b\frac{\pi}{\varepsilon}}$$

For convenience, let us write $V_C\left(\frac{\pi}{\varepsilon}\right) = V_{C1}$, then

$$V_{C1} = V_C\left(\frac{\pi}{\varepsilon}\right) = V + (V + V_{CO})e^{-b\frac{\pi}{\varepsilon}}$$

Or

$$V_{C1} = V_C\left(\frac{\pi}{\varepsilon}\right) = V + (V + V_{CO})e^{-\frac{R\pi}{2Ł\varepsilon}} \text{... (XIV)}$$

This equation (14) provides the voltage across the capacitor at the instant $t = \frac{\pi}{\varepsilon}$.

In the second mode of operation of the basic series inverter, as both the thyristors T_1 and T_2 are in the off state [1-4] as shown in figure 3, therefore, in this mode of operation, $I(t) = 0$, $V_C(t) = V_{C1}$ and $V_Ł(t) = 0$.

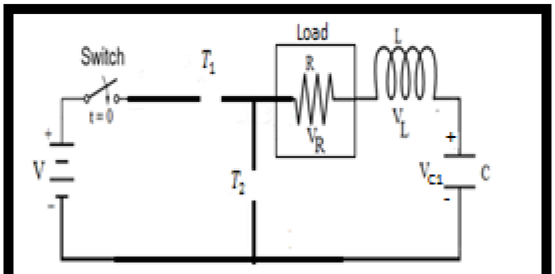

Figure 3: Equivalent Circuit (both T_1 and T_2 are off)

In the third mode of operation of the basic series inverter, since the thyristor T_1 is off and the thyristor T_2 is on, therefore, the equivalent circuit, in this case, is shown in figure 4.

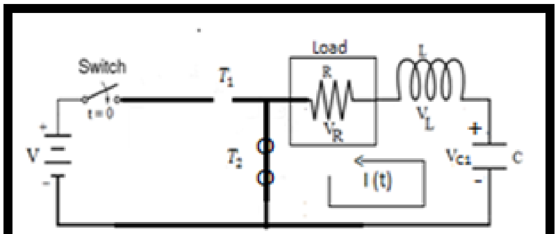

Figure 4: Equivalent Circuit (T_1 is OFF and T_2 is ON)

In this case, the capacitor is initially charged to a potentialV_{C1} with positive polarity on the upper plate and negative polarity on the lower plate. The direction of flow of current on this case is in opposite direction to that of current that flows in the first mode of operation of thebasic series inverter [1-4].

The application of Kirchhoff's loop law to the loop (shown in figure 4) provides

$\mathrm{RI(t)} + Ł[I'(t)] + \frac{q(t)}{C} = V_{C1} \ldots$ (XV)

Equation (XV) is similar to the equation (1). Here, on the right-hand side of equation (XV), the term V_{C1} appears instead of term $V + V_{CO}$ which appeared on the right-hand side of equation (I). Hence the solution of equation (XV) can be obtained in a similar manner by the Dinesh Verma Transform as that of equation (I) and is given by

$\mathrm{I(t)} = \frac{V_{C1}}{\omega Ł} e^{-\frac{R}{2Ł}t} \sin \omega t \ldots.$ (XVI)

This equation (XVI) confirms that the current $\mathrm{I(t)}$is sinusoidal in nature with exponentially decreasing amplitude. It is clear from the equations (VI) and (XVI) that the amplitude of current in the first mode of operation will be equal to the amplitude of current in the third mode of operation only if $V_{C1} = V + V_{CO}$.

***Conclusion*:**

This paper shows that the practice of Dinesh Verma Transform for getting the response (electric current) of basic series inverter. This takes up the Dinesh Verma Transform as an effective technique for gettinging the response of power electronic circuits.

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