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KHWOPA COLLEGE OF ENGINEERING

AFFILIATED TO TRIBHUVAN UNIVERSITY

A
Report on

LAB 2: THYRISTOR CONTROLLED REACTOR

Submitted By :

Shubhanga Aryal KCE078BEL038

Submitted To:

Er. Sabin Kasula

Lecturer, KhCE

Department of Electrical Engineering

KHWOPA COLLEGE OF ENGINEERING

Libali-08, Bhaktapur

LAB 2

THYRISTOR CONTROLLED REACTOR

1 Objectives

To understand the working of Thyristor Controlled Reactor and simulate it using Matlab/Simulink for various firing angles.

2 Software Used

- Matlab/Simulink

3 Theory

A Thyristor Controlled Reactor (TCR) is a reactance connected in series with a bidirectional thyristor valve. The thyristor valve is phase controlled, which allows the value of delivered reactive power to be varied to meet different system conditions. TCRs are used in transmission lines for limiting voltages on lightly loaded transmission lines.

The circuit diagram of a thyristor controlled reactor is as shown below:

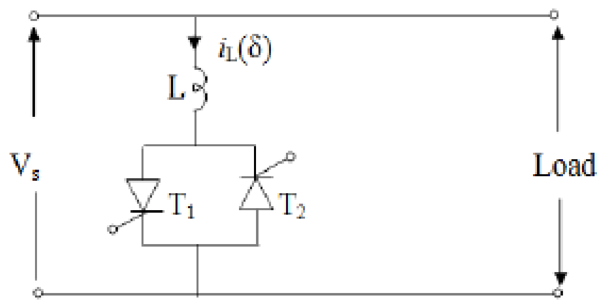

Figure 1: Circuit Diagram of Thyristor Controlled Reactor

Operating Principle of TCR

A TCR scheme has a fixed inductor L in series with an AC voltage controller consisting of thyristors T_1 and T_2 as shown in the figure above. The thyristor T_1 conducts for the positive half cycle of the reactor current and thyristor T_2 conducts for the negative half cycle of the reactor current.

The basic idea is to change the RMS value of the reactor current I_L by controlling the firing angle α. The magnitude of the reactor current changes with constant system voltage V_s and the inductor in series with the voltage controller is equivalent to $X_L(\alpha)$ as a function of firing angle.

Applying KVL to the circuit, we have:

$$V_s = L\frac{di_L}{dt} + Ri_L \tag{1}$$

The solution of the above differential equation is given by a steady and transient part as:

$$i_L = \frac{V_m}{Z}\sin(\omega t - \phi) + Ae^{-\frac{R}{L}t} \tag{2}$$

where

$$Z = \sqrt{R^2 + (\omega L)^2}$$

and

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

Solving the above equations with given initial conditions and simplifying, we get:

$$i_L(t) = \frac{V_m}{Z}\left[\sin(\omega t - \phi) - \sin(\alpha - \phi)e^{-\frac{R}{L}(t-\frac{\alpha}{\omega})}\right] \tag{3}$$

If $\alpha = \phi$, the current becomes continuous and sinusoidal.

Since $X_L >>>> R$ the above equation becomes:

$$i_L(t) = \frac{V_m}{Z}sin(\omega t - \frac{\pi}{2}) - \frac{V_m}{Z}sin(\alpha - \frac{\pi}{2}) \tag{4}$$

When alpha is equal to 90 degrees, the second part of the current becomes zero . This means that the reactor current lags the source voltage by 90 degrees. Hence alpha=90 degree is taken as the firing angle $\delta = 0$ to analyze the circuit.

$$\text{When } \alpha = \frac{\pi}{2} + \delta \quad \text{(i.e., firing angle } = \delta)$$

$$i_L = \frac{V_m}{Z}\sin\left(\alpha t - \frac{\pi}{2}\right) - \frac{V_m}{Z}\sin\delta$$

From point a to b in Figure 2,

$$\frac{V_m}{Z}\sin\left(\alpha t - \frac{\pi}{2}\right) < \frac{V_m}{Z}\sin\delta$$

Therefore, from point a to b net current iL is negative, hence T1 does not conduct from a to b. Therefore, the current waveform is not sindusodial.

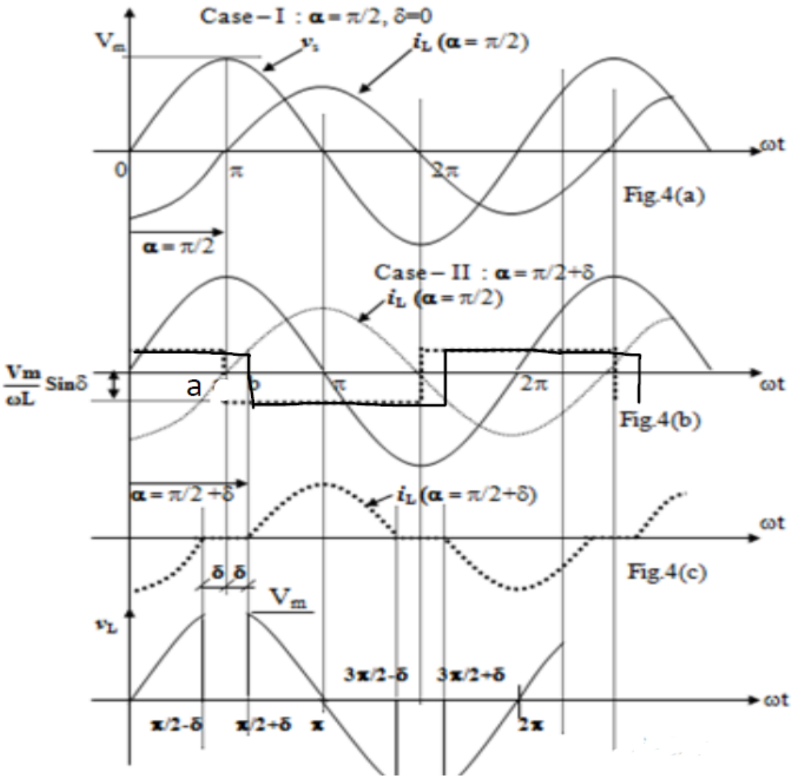

Figure 2: Waveform of TCR for Firing Angle δ

Upon fourier analysis and simplyfying the fundamental component of inductor current is:

$$I_l = \frac{V_m}{X_L}(1 - \frac{2\delta}{\pi} - \frac{sin2\delta}{\pi}). \tag{5}$$

The above equation can be written as :

$$I_L = B(\delta)V_m \tag{6}$$

where $B(\delta) = 1/X = \frac{1}{\omega L}(1 - \frac{2\delta}{\pi} - \frac{sin2\delta}{\pi})$. and $X_L = \omega L(\frac{\pi}{\pi - 2\delta + sin2\delta})$.
From the above equation it is clear that the inductive reactance X_L is a function of firing angle δ.

Since, inductor draws non sinusodial current, it causes harmonics in the system.