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Reactive Power Control Using Thyristor Controlled Tap Changer System

[1]R.Mahalakshmi and [2]K.S.R. Anjaneyalu
[1]Department of EEE, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India
[2]Department of EEE, JNTU College of Engineering, Anatapur, Andhra Pradesh, India

Abstract: If the reactive power of the load is changing rapidly, then a suitable fast response compensator is needed. SVC and TCPAR (Thyristor Control Phase Angle Reactor) are two such compensators belonging to FACTS family. A model for the Thyristor tap changer has been designed to improve the voltage level at the load end and also a smooth reactive power control is achieved by controlling the firing angle, when a R.L load is present.

Key words: Reactive power, thyristor controlled tap changer

INTRODUCTION

The possibility of controlling power flow in an electric system with out any rescheduling and topological changes can improve the power system performance (Hingorani, 1993). It is been proved that, instead of building new transmission lines, an efficient usage of the existing lines up to their thermal limit in possible (Hingorani, 1993; Gyugi, 1988; Iravani *et al*., 1994).

FACTS, which are power electronic based devices can change parameters line impedance, voltage and phase angle. Therefore they have the ability to control power flow pattern and enhance the usable capacity of the existing lines. The important feature of FACTS is that they can vary the parameters rapidly and continuously, which will allow a desirable control of the system operation.

TCPAR can alter the phase shift angle to control the power flow pattern. This component can benefit the system operation in aspects line voltage control, power factor improvement and reactive power compensation (Hingorani, 1994; Iravani and Muratukulam, 1994; Noroozian and Anderson, 1993).

This study deals with the effect of Thyristor tap changer in a power system and how well they improve the system performance on the basis of power factor and reactive power control.

THYRISTOR CONTROLLED TAP CHANGER SYSTEM

A continuously controllable thyristor tap changer can give continuous control with varying degrees of circuit complexity (Hingorani, 2001). The basic power circuit scheme of a thyristor tap changer with a resistive load is shown in Fig 1.

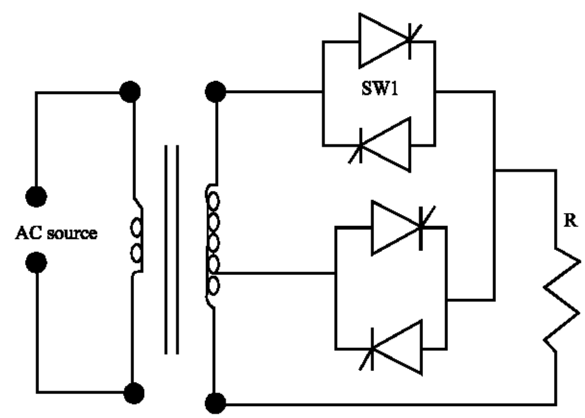

Fig. 1: Thyristor tap changer model with resistive load

RESULTS

This arrangement could give continuous voltage magnitude control by initialing the onset of the thyristor valve conduction. The circuit model for Thyristor Tap Changer is shown in Fig. 2. The two voltages obtainable at the upper and lower taps V_2 and V_1, respectively are given in Fig. 3.

This circuit has been simulated using PSPICE software. The center tap transformer is modeled using two dependent voltage sources. The gating of the thyristor valves is controlled by the delay angle • with respect to the voltage zero crossing of these voltages. With respect to the gating, the load voltage with delay angle • is shown in Fig. 4.

It shows that at • = 0, in the case of a resistive load, the current crosses zero and thus the previously conducting valve turns off, valve sw, turns on to switch the load to the lower tap. At • = •$_2$, valve sw_2 is gated on, which commutates the current from the conducting

Corresponding Author: R. Mahalakshmi, Department of EEE, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India

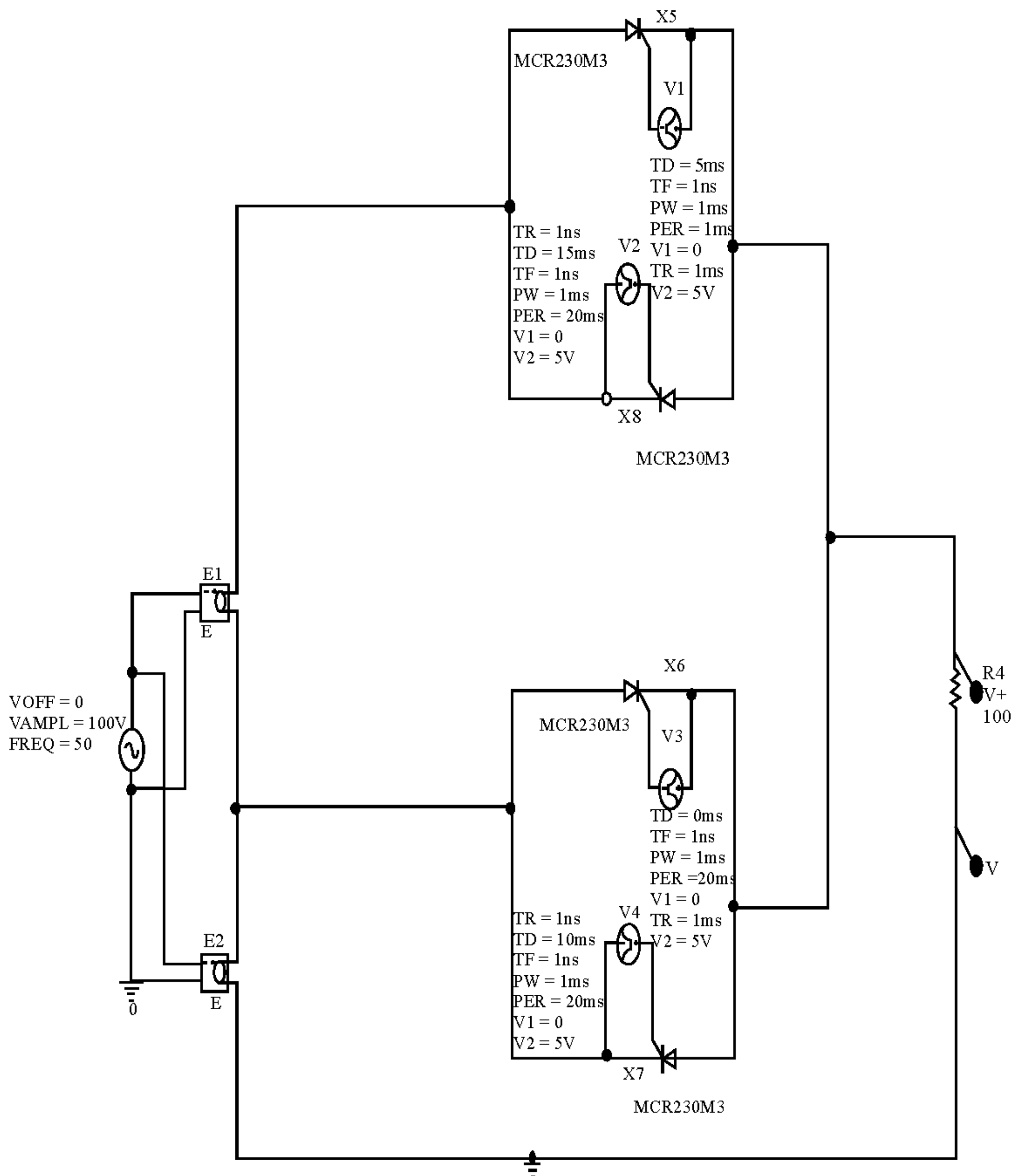

Fig. 2: Thyristor tap changer with resistive load

thyristor valve sw_1, by forcing a negative anode to cathode voltage across it and connecting the output to the upper tap voltage V_2. This valve sw_2 continues conducting until the next current zero is reached, where the previous gating sequence continues. On inspection of this waveform, by delaying the turn on of sw_2 from zero to •, any voltage between V_2 and V_1 can be attained.

Fourier analysis of the output voltage waveform for idealized continuously controlled thyristor tap changer, operating between voltages v_1 and v_2 with resistive load and delay angle • with respect to zero crossing of voltage, can be yielding the expression for fundamental component:

$$V_{0f} = \sqrt{a_1^2 + b_1^2}$$

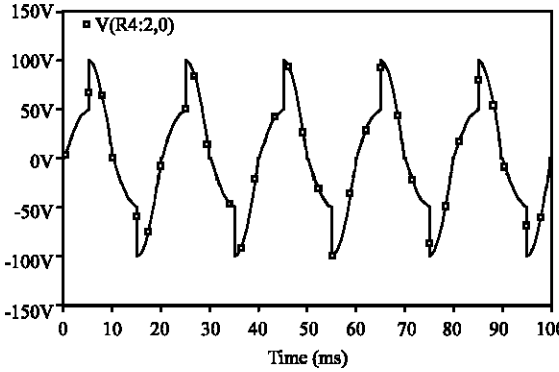

Fig. 3: Upper and lower tap voltages

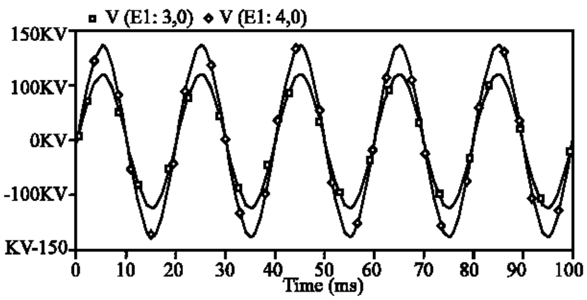

Fig. 4: Load voltage with delay angle •

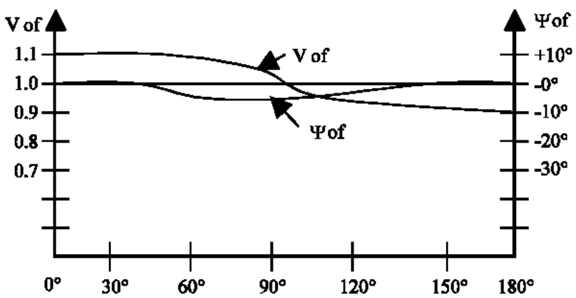

Fig. 5: Variation of amplitude

$$? _{0f} = \tan^{-1}\left(\frac{a_1}{b_1}\right)$$

Where

V_{of} = Amplitude of the fundamental and

$\bullet_{of}$ = Phase angle of the fundamental with respect to unregulated voltage and

$$a_1 = \left(\frac{V_2 - V_1}{2\pi}\right)(\cos 2\alpha - 1)$$

$$b_1 = V_1 + \left(\frac{V_2 + V_1}{\pi}\right)\left(\pi - \alpha + \frac{\sin 2\alpha}{2}\right)$$

The variation of amplitude V_{of} and $\bullet_{of}$ of the fundamental voltage V_{of} with delay angle • for an assumed ± 10% regulation rauge (V_1 = 0.9 and V_2 = 1.1 ou) is shown in Fig 5.

THYRISTOR TAP CHANGER SYSTEM WITH RL LOAD

The same circuit with a reactive load (R-L load) with $X_L > R$, is simulated. Then for various values of the gating angle •, the reactive power at the load end is tabulated. The circuit model with R-L load is shown in Fig. 6 and the corresponding results are tabulated in Table 1. The reactive powers as percentage of secondary voltages are also tabulated in Table 2. The output waveform is as in Fig. 7.

The Fourier analysis of the above voltage waveform is done and the corresponding spectrum is given in Fig. 8. The Fourier component of the response is also tabulated.

Table 1: Reactive power at different firing angles

	Firing angle (deg)				
	Lower tap		Upper tap		
	S_a	S_b	S_c	S_d	Reactive power
S. No.	$\bullet_1$	$\bullet_2$	$\bullet_3$	$\bullet_4$	(MVAR)
1	0	180	90	270	1100
2	0	180	126	306	1000
3	0	180	162	342	950

Table 2: Variation of reactive power for different upper and lower tap voltages as percentage of secondary voltage

S. No.	Upper tam voltage (V) (as percentage of secondary voltage)	Lower tap voltage (V) (as percentage of secondary voltage)	Reactive power (MVAR)
1	10	90	1130
2	20	80	1000
3	40	60	950

Fourier Components of Transient Response V(R_R1)

No (HZ) Component Component (DEG) Phase (DEG)

1	5.000E+01	1.409E+02	1.000E+00	1.579E+02	0.000E+00
2	1.000E+02	9.803E+00	6.960E-02	-1.388E+01	-3.297E+02
3	1.500E+02	1.213E+01	8.614E-02	4.411E+01	-4.296E+02
4	2.000E+02	1.211E+00	8.596E-03	1.674E+02	-4.642E+02
5	2.500E+02	2.522E+00	1.790E-02	-1.062E+02	-8.957E+02
6	3.000E+02	8.475E-01	6.016E-03	-4.190E+01	-9.893E+02
7	3.500E+02	2.041E+00	1.449E-02	5.177E+01	-1.054E+03

Total Harmonic Distortion = 1.135959E+01 Percent

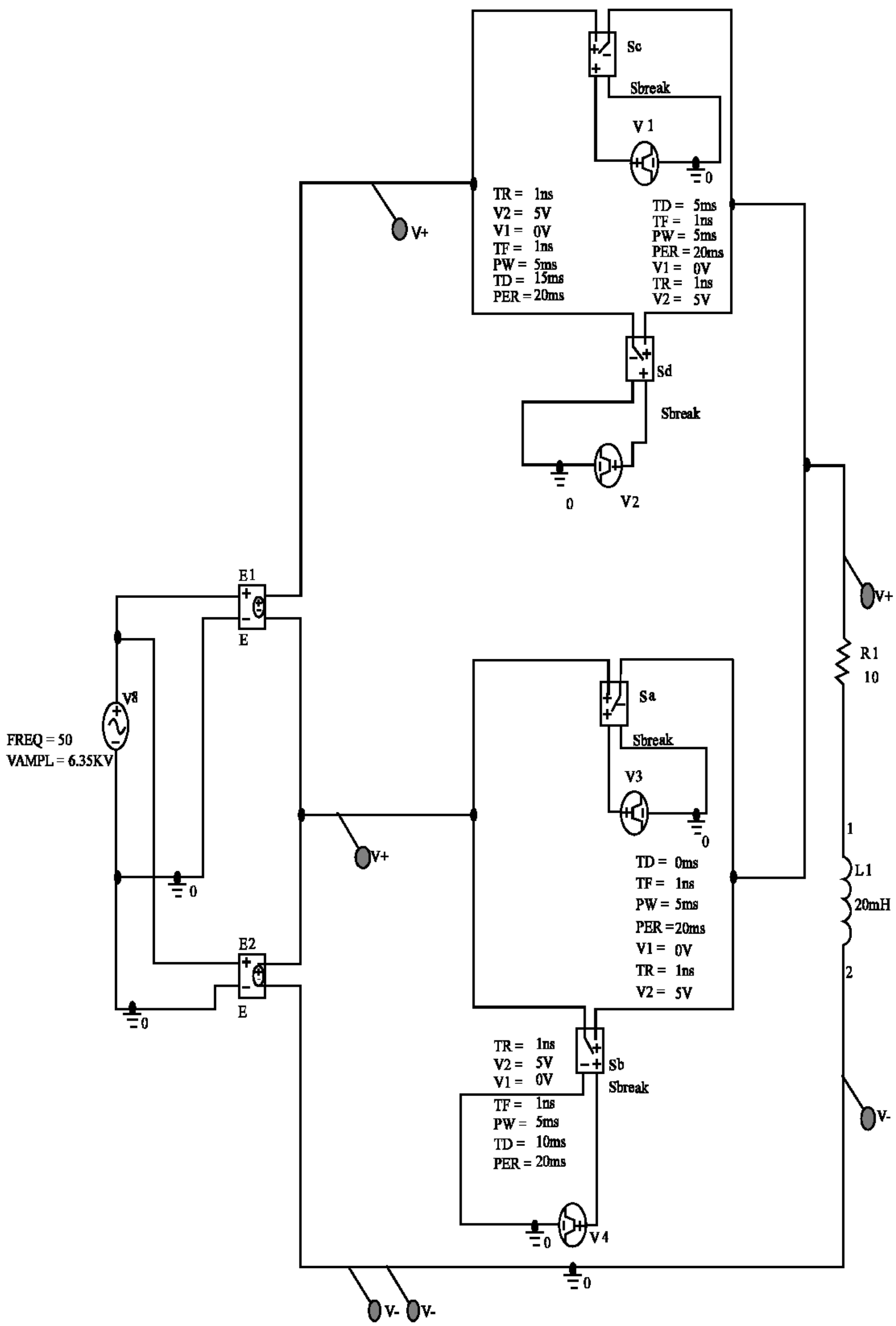

Fig. 6: Thyristor tap changer with RL load

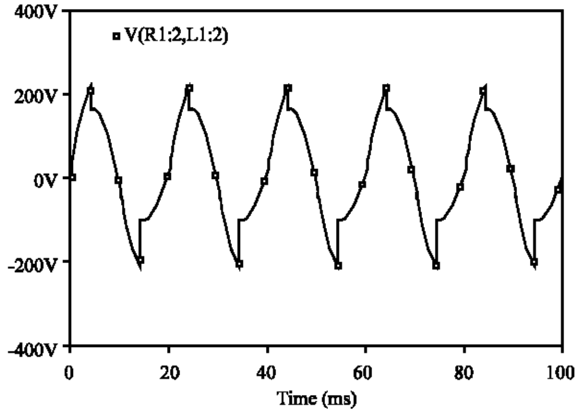

Fig. 7: Load voltage of thyristor tap changer with RL load

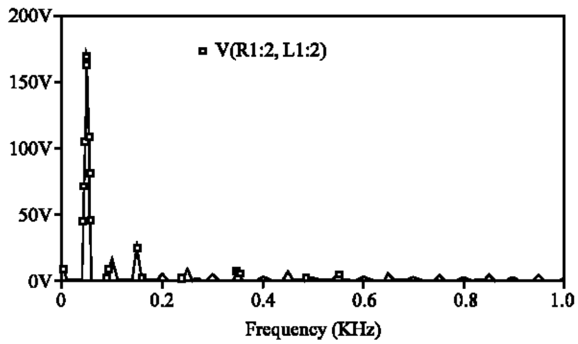

Fig. 8: Fourier analysis of load voltage

CONCLUSION

The Thyristor controlled Tap Changer is analyzed and the circuit model for the system is developed using the blocks available in PSPICE. The Thyristor controlled Tap Changer system is simulated with R and RL loads and the results are presented. The variation of reactive power with change in firing angle is also tabulated. The frequency spectrum of the output voltage is presented. The simulation results closely agree with the theoretical results. The static on load tap changer system has advantages like spark free operation, reduced maintenance and improved response. Therefore the static tap changer system is a viable alternative to the existing on load tap changer system. This system suffers from the drawback of the output harmonics due to the chopped voltage across the load.

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