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Website- www.aarf.asia, **Email** : editor@aarf.asia , editoraarf@gmail.com

CHOICE OF STATIC VAR COMPENSATOR (SVC), MODELING AND DETERMINATION OF ITS POWER FACTOR CORRECTION (PFC) CAPABILITY IN A.C. TRANSMISSION LINE

Ibekwe B.E[Ph.D]
Department of Electrical and Electronic Engineering, Faculty of Engineering
Enugu State University of Science and Technology (ESUT), Enugu

Chiwetalu U. J.
Department of Agricultural and Bio-resources Engineering, Faculty of Engineering
Enugu State University of Science and Technology (ESUT)

Eje, B.E
Department of Agriculture and Bio-resource Engineering,
Enugu State University of Science and Technology

Abstract
The Power Factor Correction (PFC) capability of Static Var Compensator (SVC) in a.c. transmission line is presented. SVC P.F.C capability is very important because it can help to adjust the line reactive power to control the system voltage. This is implemented by using a circuit configuration of self-commutated Pulse Width Modulation (PWM) converter system consisting of Thyristor Controlled Reactor (TCR) and Fixed Capacitors (FC). The end result is that the line current tracked the voltage, thus improving the system PF significantly to about 98%.

Key words: a.c. transmission line, SVC, PFC, PWM converters, Flexible AC Transmission System (FACTS).

1.0 Introduction

Of all the FACTS controllers researched, which included the first and the second generation of these devices, the SVC was chosen based on the following simple reasons: [3]

- It is capable of providing continuous and rapid control of reactive power and voltages.
- It can enhance several other aspects of transmission line performance such as:

(i) Control of temporary (power frequency) over voltages
(ii) Prevention of voltage collapse

(iii) Enhancement of transient stability

(iv) Enhancement of damping of system oscillation.

At the sub-transmission and distribution system levels, SVCs are used for balancing the unbalanced three phase system supplying unbalanced loads. They are also used to minimize fluctuations in supply voltage caused by repetitive-impact loads e.g. the dragline loads of mining plants, rolling mills and arc-furnaces [6].

2.0 Development of the SVS Model

From power system operation viewpoint, the static var system (SVS) is equivalent to a shunt capacitor and a shunt inductor both of which can be adjusted to control voltage and reactive power at its terminals or nearby bus in a prescribed manner. Figure 2.1 is an idealized static var system model [1].

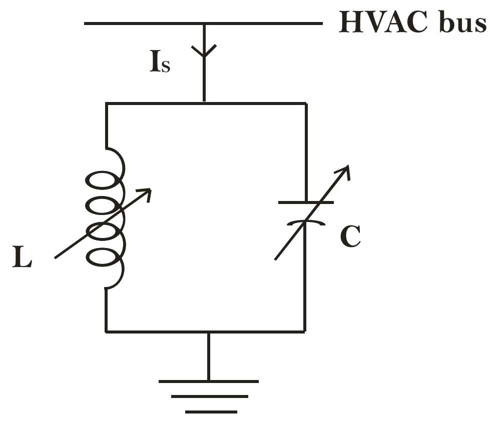
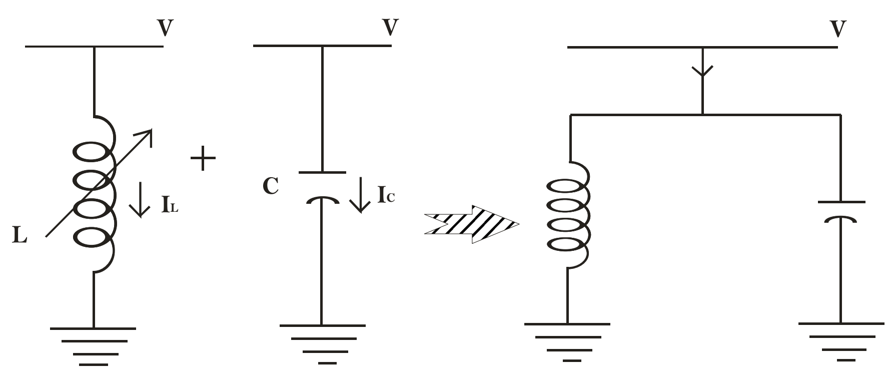


Fig. 2.1: Idealized static var system model

An ideal SVS should hold constant voltage, possess unlimited var generation/absorption capability with no active or reactive power losses [6].

However, the realistic or practical SVS is composed of a controllable reactor and a fixed capacitor. The resulting characteristics are essentially applied to a wide range of practical SVS configurations. Figure 2.2 illustrates the derivation of the characteristics of an SVS, made up of a controllable reactor and a fixed capacitor (FC). The component characteristic is derived by adding the individual characteristics of the components as shown [1].



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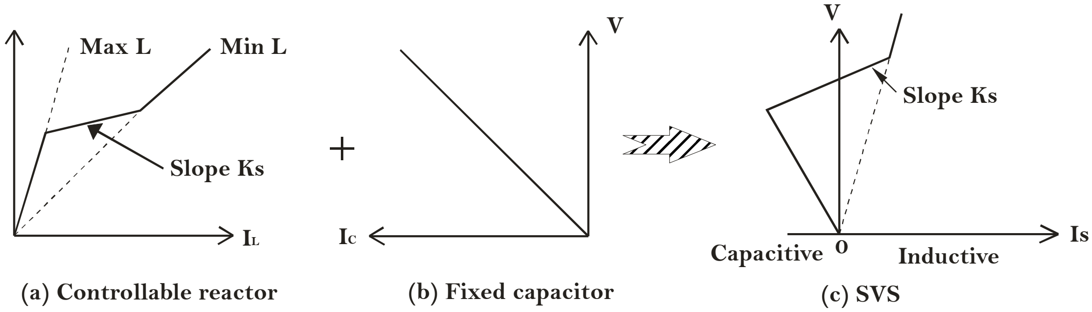

Figure 2.2 composite characteristics of an SVS.

The basic elements of a Thyristor Controlled Reactor (TCR) are a reactor in series with a bidirectional thyristors switch (Fig. 2.3). The thyristors conduct on alternate half-cycles of supply frequency depending on the firing angle α measured from a zero crossing of voltage.

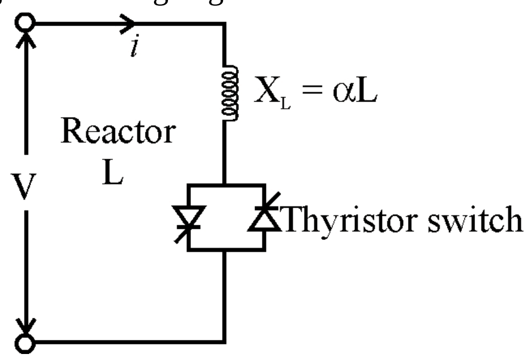

Figure 2.3: Basic Elements of TCR

Let σ be the conduction angle, related to α by

$$\sigma = 2(\pi - \alpha) \qquad \ldots\ldots\ldots.. \qquad 2.1\ [1].$$

Fourier analysis of the current waveform gives the fundamental components.

$$I_I = \frac{V}{X_L}\frac{\sigma - sin\sigma}{\pi} \qquad \ldots\ldots\ldots.. \qquad 2.2\ [1].$$

In effect, the TCR is a controllable susceptance. The effective susceptance as a function of the firing angle α is given by:

$$B(\propto) = \frac{I}{V} = \frac{\sigma - sin\sigma}{\pi \times L} \qquad \ldots\ldots\ldots.. \qquad 2.3\ [1].$$

Substituting equation 2.1 into 2.3 gives

$$B(\propto) = \frac{2(\propto - \sigma) + sin\,2\propto}{\pi \times L} \qquad \ldots\ldots\ldots.. \qquad 2.4\ [3].$$

Where Σ is the conduction angles

X_L is the reactance of the reactor at a fundamental frequency.

From equation 2.3 and 2.4, the system voltage is given by:

$$V = \frac{I,\pi X_L}{2(\propto - \sigma) + sin\ 2\propto} \qquad \ldots\ldots\ldots.. \qquad 2.5\ [3].$$

3.0 SVC Power Factor Correction (PFC) Capability in Power System

Power factor correction (PFC) can be defined as a way of counteracting the undesirable effects of electric load that create power factor less than unity [3]. To determine the SVC PFC capability in a system is very important because it helps to adjust the reactive power to control the system voltage. To implement this, a circuit configuration with a resistive load consisting of TCR +FC, obtained from self-commutated PWM converter system was used.

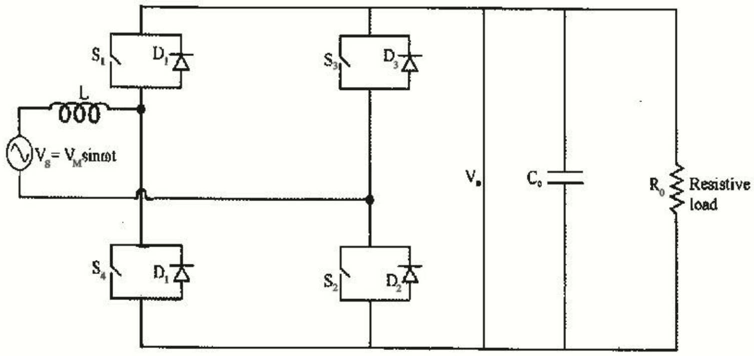

Figure 3.1: Circuit 1 with a resistive load

Analysis of the Circuit

(a) S_1 S_2 closed (current decreasing):

Current loop: $V_s \rightarrow L \rightarrow D_l \rightarrow V_o \rightarrow D_2 \rightarrow V_s$

Equation:

$$V_s - \frac{Ldis}{dt} - V_0 = 0$$

$$\frac{dis}{dt} = (1/L)\ \underbrace{[V_s - V_0]}_{\text{current decreasing}}$$

$$= [V_m \sin \omega t - V_0]/L \qquad 3.1$$

Again,

$$i_C = C_0 d\frac{V_0}{dt}$$

$$i_R = \frac{V_0}{R}$$

$$i_S = i_C + i_R = C_0 d\frac{V_0}{dt} + \frac{V_0}{R} = 0$$

$$i_S - C_0 d\frac{V_0}{dt} - \frac{V_0}{R} = 0$$

$$d\frac{V_0}{dt} = \left(\frac{1}{C_0}\right)\left[i_S - \frac{V_0}{R}\right] \qquad 3.2$$

(b) S_3 S_4 closed (current increasing):

Current loop: $V_s \rightarrow L \rightarrow S_4 \rightarrow V_0 \rightarrow S_3 \rightarrow V_s$

Equation:

$$V_s - \frac{Ldis}{dt} + V_0 = 0$$

$$\frac{di_s}{dt} = (1/L)\underbrace{[V_s + V_0]}_{\text{current increasing}}$$

$$\frac{dis}{dt} = (1/L)[V_m \sin\omega t + V_0] \qquad 3.3$$

Again,

$$i_C = C_0 d\frac{V_0}{dt}$$

$$i_R = \frac{V_0}{R}$$

$$i_S - i_C - i_R$$

$$\therefore \quad i_S = -C_0 d\frac{V_0}{dt} - \frac{V_0}{R}$$

$$i_S + C_0 d\frac{V_0}{dt} + \frac{V_0}{R} = 0$$

$$C_o d\frac{V_0}{dt} = -i_S - \frac{V_0}{R}$$

$$\therefore \quad d\frac{V_0}{dt} = \frac{-1}{C_O}\left[I_S + V_O/R\right] \qquad 3.4$$

3.1 Simulation Results

The circuit equations were loaded with the parameters defined below:

$V_s = 220\sqrt{2}$, ωt = 2πft, switching period 4kHz. Assume ac and dc input power filters as L = 5mH, C = 0.6F, and load resistance of R = 20Ω. And the four equations were solved in MATLAB using Runge-Kuta; thus the plot of the output voltage and current waveforms are shown in figure 3.2.

4. Conclusion

The computer simulated curves for Figure 3.2 showed that current had tracked the voltage thus, improved the power factor significantly to about 98%. Note that a high load power factor brings about an overall system balance in addition to the following:

(i) Improvement of voltage regulation

(ii) Enhancement of transmission system efficiency

(iii) Elimination of current harmonic components in a system. Hence, power factor correction is an important tool to control the reactive power and improve the system voltage.

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