4.7 MODELING OF THE SVC FOR POWER-SYSTEM STUDIES

The extent of modeling of the SVC and the power system is dependent on the nature of the power-system studies to be performed. In this section, the basic SVC modeling concepts involved in different power-system studies are presented.

4.7.1 Modeling for Load-Flow Studies

The SVC models in these studies should represent the fundamental-frequency, steady-state, and balanced performance of the SVC [3], [11], [14], [25], [26]. It may be necessary to model the SVC in terms of its three individual phases when an unbalanced operation of the SVC is considered, such as during load compensation or voltage balancing. The features of conventional load-flow programs are described in the text that follows.

4.7.1.1 SVC Operation Within the Control Range

If the slope of the SVC is neglected, then the SVC is modeled as a PV bus, with \( P = 0 \) and \( V = V_{\text{ref}} \). However, if the slope is considered (as in the analysis of weak ac systems), the same is modeled by connecting the high-voltage side of the SVC bus to a fictitious auxiliary bus by means of a reactance equal to the slope expressed in per units on the SVC base. Such a model is shown in Fig. 4.26(a).

![Figure 4.26](image)

Figure 4.26 The SVC models with slope representation using conventional power-flow PV buses: (a) without a coupling transformer and (b) with a coupling transformer.
Figure 4.27 The SVC model with slope for operation outside the control range.

It may become necessary to model the coupling transformer should the SVC be connected to the tertiary winding. When the transformer is represented explicitly, the susceptance range of the SVC must be appropriately adjusted to represent the correct reactive-power rating as seen at the high-voltage bus [11]. The corresponding load-flow model is illustrated in Fig. 4.26(b).

4.7.1.2 SVC Operation Outside the Control Range The SVC is represented as an appropriate shunt admittance, depending on which limit is violated [3].

If $I_{SVC} > I_{\text{max}}$ (the inductive-limit violation), then

$$B = B_{\text{min}} = \frac{Q_{\text{max}}}{V_{\text{max}}^2}$$

(4.61)

If $V < V_{\text{min}}$ (the capacitive-limit violation), then

$$B = B_{\text{max}} = \frac{Q_{\text{min}}}{V_{\text{min}}^2}$$

(4.62)

where $Q_{\text{max}} =$ the maximum inductive-reactive-power rating at $V_{SVC} = V_{\text{max}}$

$Q_{\text{min}} =$ the maximum capacitive-reactive-power rating at $V_{SVC} = V_{\text{min}}$

It may be noted that $Q_{\text{max}}$ is a positive quantity, whereas $Q_{\text{min}}$ is a negative quantity.

The SVC model in this case is shown in Fig. 4.27. Modeling of the SVC as a PV node with $Q$ limits is not appropriate for representing the SVC under overload conditions. This characterizes an incorrect behavior outside the control range, as depicted in Fig. 4.28.

In advanced load-flow programs, a comprehensive SVC model is used that models not only the slope in the controlled range but also the $Q$ limits in the uncontrolled domain [3], [11].
4.7.2 Modeling for Small- and Large-Disturbance Studies

In these studies, only the positive-sequence behavior of the SVC-compensated system is modeled. The electromagnetic transients in the SVC (TSC, TCR) and the network can be neglected if the objective is to investigate the stability related to electromechanical oscillations.

The models corresponding to the different components of the control system have already been presented. Because the bandwidth of stability programs is limited, the thyristor firing control is not explicitly represented. In such a case, a suitable interface model is needed to convert the output signal $B_{\text{ref}}$ into a controlled network component connected to the SVC bus. This can be implemented using any of the two models shown in Fig. 4.29 and listed as follows:

1. The variable-susceptance model, in which the SVC current in response to the susceptance output is given by

$$I_{\text{SVC}} = B_{\text{ref}} V_{\text{SVC}}$$  \hspace{1cm} (4.63)

\begin{figure}[h]
\centering
\begin{subfigure}{0.45\textwidth}
\centering
\includegraphics[width=\textwidth]{a.png}
\caption{(a) The susceptance model and (b) the current-source model.}
\end{subfigure}
\end{figure}
2. The controlled-current-source model, in which the SVC current is again given as

\[ I_{\text{SVC}} = B_{\text{ref}} V_{\text{SVC}} \]  \hspace{1cm} (4.64)

Although both models in the preceding list are equivalent, a significance difference exists in their implementation. In case of the variable-susceptance model, the system-admittance matrix \( B \) must be updated in case any changes occur in \( B_{\text{ref}} \), whereas a constant \( B \) matrix can continue to be used in case of the controlled-current-source model.

### 4.7.3 Modeling for Subsynchronous Resonance (SSR) Studies

In subsynchronous resonance (SSR) studies [43], a wide bandwidth of electromechanical frequencies is considered, so a need exists to model the network transients, as well as the thyristor-controlled and thyristor-switched elements. Additional filtering in the measurement systems may be required to eliminate network-resonant frequencies close to fundamental for the satisfactory, stable operation of the SVC control system. These aspects are discussed in detail in Chapter 5.

### 4.7.4 Modeling for Electromagnetic-Transient Studies

The requirements for modeling the SVC in a general electromagnetic-transient study [3], [13], [14], [21]–[24] are

1. representation of three phases;
2. accuracy over a wide frequency range;
3. representation of all system nonlinearities, as well as different controls and protection functions;
4. time-domain simulation;
5. detailed modeling of the static var system components (e.g., reactors, capacitors, and transformer models—including their saturation characteristics);
6. representation of the GPG system and synchronizing system for studying the instant-to-instant behavior of SVCs; and
7. modeling of additional control and protection functions.

### 4.7.5 Modeling for Harmonic-Performance Studies

The basic SVC model required for conducting harmonic-performance studies [2], [3] comprises an ideal harmonic-current source (single-phase or 3-phase symmetrical) with a specified current spectrum. The magnitudes of the \( n \)-th order harmonic current, \( I_n \), are dependent on the SVC configuration and its
operating condition. A harmonic-voltage source model in series with a variable source admittance is proposed in ref. [27]. Harmonic-performance studies are based on certain assumptions, as follows:

1. The effect of multiple harmonic sources can be investigated by applying the superposition principle.
2. The SVC harmonic generation can be modeled by positive-, negative-, and zero-sequence harmonic sources.
3. The system can be represented by linear models at each harmonic frequency.
4. The precise evaluation of harmonic distortion must have accurate load modeling.