Assessment of Methodologies for Modeling SVCs in the Power Flow Problem

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Abstract:
This paper assesses the main methodologies for representing static var compensators (SVCs) steady-state behavior in the power flow problem. Different control approaches are considered in each of the models presented, which results in the adoption of the following other state variables: (*i*) reactive power injected; (*ii*) current injected; and (*iii*) thyristor firing-angle. Despite their differences, a *full* Newton method is considered for all methodologies by means of incorporating the respective control equation into the power flow system of nonlinear equations. All propositions were simulated on two different test systems: a 4-bus tutorial system and the IEEE benchmark Nordic system. A Python-based program was developed, and the result simulations were validated by CEPEL's (Electric Energy Research Center) production-grade academic version software.

Keywords: Static VAr Compensator; *Full* Newton Method; Power Flow; Control Device; FACTS; Voltage Control.

1. INTRODUCTION

Electrical Power Systems (EPSs) are characterized by being complex networks both in terms of topology, due to the possibly high number of buses and electrical connections it may present, as in terms of operation, due to the possibly high number of actively operating electrical equipment connected at it. Considering the latter, the electrical equipment are responsible for maintaining the operation condition of EPSs at acceptable levels of security, reliability, robustness, quality, and stability. This minimal operational condition is normally regulated by Transmission System Operators (TSO) and Distribution System Operators (DSO).

In order to analyze the operation condition of EPSs under different topology configurations, the mathematical power equations that model the network behavior are applied to precise and efficient computational simulations (Stott, 1974; Kundur, 1994). Through the application of numerical methods, such as Newton-Raphson's (Tinney and Hart, 1967), it is possible to obtain valuable information (buses voltage magnitude, phase angles, reactive power injection, and others) about an EPS's behavior upon the wide variety of generation and load scenarios it is subjected to.

On account of the power flow simulation results, an EPS is considered voltage stable once all bus magnitudes are within a specific interval level, given load disturbances (Hatziargyriou et al., 2020). This condition is of crucial importance for the correct operational planning of EPSs, and can be circumvented by the implementation of devices capable of controlling the flow, production, and absorption of reactive power in the network (Kundur, 1994; Ambriz-Perez et al., 2000).

Within this frame of reference Static VAr Compensators (SVCs) are introduced into EPSs. By means of injection or absorption of reactive power into or from the power network, respectively, the SVC is able to enhance a specific controlled bus voltage magnitude around a reference value. This enhancement is also noticed in the EPS Voltage Stability Margin (VSM) (Miller et al., 1982; Perez et al., 2000), emphasizing the positive impact that this electrical equipment promotes on the power system in which it is actively operating.

Despite being recently developed control devices due to the rising research in power electronics, SVC precise modeling is of key importance for correctly analyzing EPSs operational behavior. At first, SVCs were ideally modeled as generators operating as synchronous condensers (Erinmez, 1986; Taylor et al., 1994). This model, however, leads to a series of errors once the device is operating near its limits (Alvarado and DeMarco, 1995). As an alternative, new steady-state methodologies for representing SVC in the power flow analysis were proposed by Ambriz-Perez et al. (2000) and Passos Filho (2000). The former proposes two new models, which are based on the SVC's total susceptance and thyristor firing-angle values. The latter, in turn, developed two other methodologies for the SVC, which are based on the device's reactive power injection and current injection characteristic curves.

Regardless of the different adopted approaches in each methodology, all four are able to correctly model the steady-state behavior of the control device. Nevertheless, an enhancement to the thyristor firing-angle (and consequently the total susceptance) methodology proposed by Ambriz-Perez et al. (2000) must be made in order to consider a *droop* variation in the controlled bus voltage magnitude (Taylor et al., 1994), as highlighted by Barbosa and Passos Filho (2022). In general, values between 1% and 5% are adopted for the *droop* variable Miller et al. (1982); Taylor et al. (1994).

In this paper, a comparative analysis between the aforementioned SVC's thyristor firing-angle, reactive power injection and current injection methodologies is made. The SVC total susceptance methodology was not considered in this study due to the fact that it consists of a simplification of the thyristor firing-angle methodology. In all methodologies simulated, the *full* Newton method was implemented in the power flow problem, in which the linearized control equations of each model are incorporated into the Jacobian matrix. In addition, the analyzed methodologies were evaluated in two test systems: a 4-bus tutorial system and the IEEE benchmark Nordic system. For validation purposes, the production-grade academic version software developed by CEPEL (Electric Energy Research Center) was used in this research, as simulations were performed in a Python-based program.

This work will be divided as follows: Section 2 will review the main methodologies for representing SVCs in the power flow problem, altogether with a disclosure to the *full* Newton method. In Section 3, the results will be presented, with the validation of traditional methodologies. Finally, Section 4 will present the main conclusions regarding the work and results obtained.

2. STATIC VAR COMPENSATOR

As previously stated, SVCs are control devices recently developed due to the rising research in power electronics, integrating the group of Flexible AC Transmission System (FACTS) devices. These FACTS devices are responsible for increasing the reliability and efficiency of EPSs operations (Taylor et al., 1994; Mathur and Varma, 2002), by means of a fast response of reactive power injection or absorption for voltage magnitude control (Erinmez, 1986).

Among the multiple constructive topologies for the SVC, the Fixed-Capacitor Thyristor-Controlled Reactor (FC-TCR) is one of the most commonly adopted in research and real-life operations (Kundur, 1994; Taylor et al., 1994), and is illustrated in Figure 1. The thyristor switches presented determine the equivalent reactance and are responsible for determining the equipment's fast control response. The SVC is commonly connected to the EPSs by means of a step-down transformer (Miller et al., 1982; Kundur, 1994), and it is able to control its own bus (k) or an electric near bus (m) voltage magnitude around a reference value.

Hereinafter, the aforementioned methodologies were developed to represent the steady-state behavior of the SVC in the power flow problem. The first two subsections will be devoted to detailing the methodologies developed by Passos Filho (2000). Following, the model developed by Ambriz-Perez et al. (2000) will be presented, considering the improvement proposed by Barbosa and Passos Filho (2022). The proposed *full* Newton method, by which these methodologies are implemented, is presented in a concluding subsection.

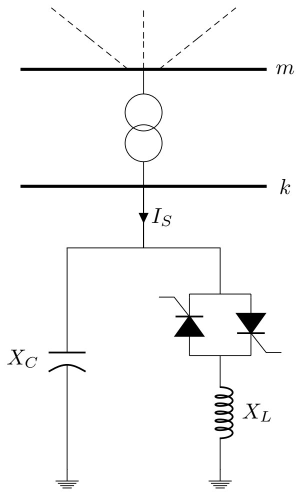

Figure 1. Static VAr Compensator FC-TCR topology.

2.1 Reactive Power Injection Methodology

The reactive power injection methodology proposed by Passos Filho (2000) consists of mathematical equations that model the steady-state behavior of the SVC according to its controlled bus voltage magnitude ($V_{m,\,svc}$) per reactive power injection ($Q_{G_k,\,svc}$) characteristic. From the characteristic curve, which is illustrated by Figure 2, the author determines three different operational regions for the control device: capacitive, linear, and inductive.

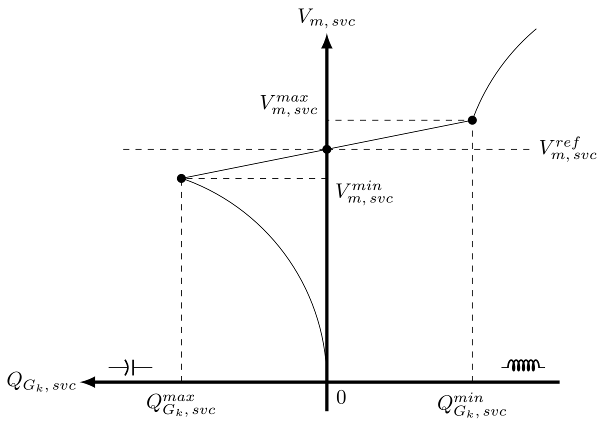

Figure 2. Static VAr Compensator controlled bus voltage magnitude per reactive power injection characteristic.

The SVC capacitive, linear, and inductive operational regions are mathematically modeled by (1), (2) and (3), respectively. The capacitive and inductive operational regions are defined by second-order equations, whereas a first-order equation defines the linear operational region. The variable "r" present in (2) models the SVC controlled bus voltage magnitude ($V_{m,\,svc}$) *droop* around a reference value ($V^{ref}_{m,\,svc}$) according to the network behavior, and is defined by (4).

$$y = Q_{G_k,\,svc} - V^2_{k,\,svc} \cdot B^{max}_{svc} \tag{1}$$

$$y = V_{m,\,svc} - V^{ref}_{m,\,svc} - r \cdot Q_{G_k,\,svc} \tag{2}$$

$$y = Q_{G_k,\,svc} - V_{k,\,svc}^2 \cdot B_{svc}^{min} \tag{3}$$

$$r = \frac{V_{m,\,svc}^{min} - V_{m,\,svc}^{max}}{Q_{G_k,\,svc}^{max} - Q_{G_k,\,svc}^{min}} \tag{4}$$

In this methodology, the reactive power injected by the SVC ($Q_{G_k,\,svc}$) is considered the new state variable (or control variable). This methodology is well-suited for studies on the impacts of reactive power injection in EPSs.

2.2 Current Injection Methodology

Similarly to the previous methodology, Passos Filho (2000) models the steady-state behavior of the SVC in the current injection methodology based on the device's controlled bus voltage magnitude ($V_{m,\,svc}$) per current generation ($I_{G_k,\,svc}$) characteristic. From the characteristic curve illustrated by Figure 3, the author once again proposes mathematical equations in accordance with the capacitive, linear, and inductive operational regions for the control device.

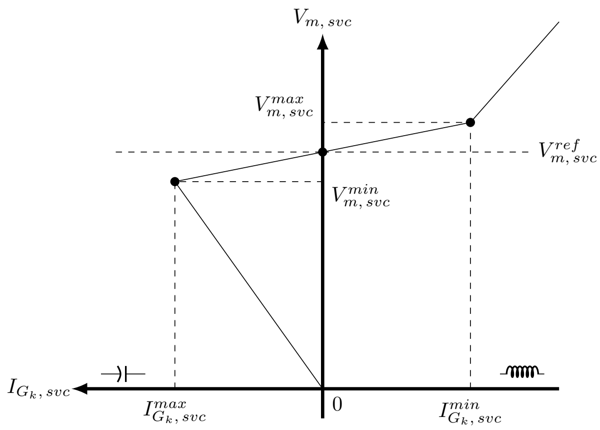

Figure 3. Static VAr Compensator controlled bus voltage magnitude per current generation characteristic.

In this methodology, the SVC capacitive, linear, and inductive operational regions are mathematically modeled by (5), (6) and (7), respectively. Compared to the model presented in Subsection 2.1, all the operational regions are defined by first-order equations. The variable "r" present in (6) models the SVC controlled bus voltage magnitude ($V_{m,\,svc}$) *droop* around a reference value ($V_{m,\,svc}^{ref}$) according to the network behavior, and is defined by (8).

$$y = I_{G_k,\,svc} - V_{k,\,svc} \cdot B_{svc}^{max} \tag{5}$$

$$y = V_{m,\,svc} - V_{m,\,svc}^{ref} - r \cdot I_{G_k,\,svc} \tag{6}$$

$$y = I_{G_k,\,svc} - V_{k,\,svc} \cdot B_{svc}^{min} \tag{7}$$

$$r = \frac{V_{m,\,svc}^{min} - V_{m,\,svc}^{max}}{I_{G_k,\,svc}^{max} - I_{G_k,\,svc}^{min}} \tag{8}$$

$$I_{G_k,\,svc} = \frac{Q_{G_k,\,svc}}{V_{k,\,svc}} \tag{9}$$

In this methodology, however, the current injected by the SVC ($I_{G_k,\,svc}$) is considered the new state variable (or control variable). This methodology is best appropriate for studies related to the impacts of current injection in EPSs and also for a rectangular formulation approach to the power flow problem. Additionally, the relationship between SVC's reactive power injection and current injection is defined by (9). By means of this equation, the SVC reactive power injection and current injection methodologies are correlated.

2.3 Thyristor Firing-Angle Methodology

The thyristor firing-angle methodology proposed by Ambriz-Perez et al. (2000) consists of the mathematical relationship between the SVC's thyristor firing-angle variable ($\alpha_{k,\,svc}$) and the equipment's equivalent reactance (X_{eq}) and equivalent susceptance (B_{eq}) values. These equations are respectively defined by (10) and (11) and correspond to the SVC FC-TCR topology (Miller et al., 1982; Erinmez, 1986; Kundur, 1994).

$$x_{eq}\left(\alpha_{k,\,svc}\right) = \frac{X_C \cdot X_L}{\left(\frac{X_C}{\pi}\right) \cdot \left[2 \cdot \left(\pi - \alpha_{k,\,svc}\right) + \sin\left(2\alpha_{k,\,svc}\right)\right] - X_L} \tag{10}$$

$$b_{eq}\left(\alpha_{k,\,svc}\right) = -\frac{\left(\frac{X_C}{\pi}\right) \cdot \left[2 \cdot \left(\pi - \alpha_{k,\,svc}\right) + \sin\left(2\alpha_{k,\,svc}\right)\right] - X_L}{X_C \cdot X_L} \tag{11}$$

Given that the SVC thyristor firing-angle value must vary between 90° and 180°, the equipment's equivalent susceptance and equivalent reactance characteristic are better illustrated by Figures 4(a) and 4(b), respectively. Due to a steady-state resonance characteristic, which depends on the ratio between X_C and X_L, the SVC's equivalent reactance presents a discontinuity at $\alpha_{k,\,svc}^0$. This condition introduces numerical and computational burdens in power flow simulations. Therefore, as proposed by Ambriz-Perez et al. (2000), it is opted to use the SVC's equivalent susceptance to model the equipment's steady-state behavior. The equivalent susceptance characteristic is continuous over the range of $\alpha_{k,\,svc}$, which allows a better model linearization in the power flow problem.

In accordance with Barbosa and Passos Filho (2022), the capacitive, linear, and inductive operational regions that model the steady-state behavior of the SVC in the power flow problem are detailed by (12), (13) and (14), respectively. The capacitive and inductive operational regions are defined by second-order equations, whereas a first-order equation defines the linear operational region. The variable "r" present in (13) models the SVC controlled bus voltage magnitude ($V_{m,\,svc}$) *droop* around a reference value ($V_{m,\,svc}^{ref}$) according to the network behavior, and is defined by (16).

$$y = \alpha_{k,\,svc} - 180° \tag{12}$$

$$y = V_{m,\,svc} - V_{m,\,svc}^{ref} - r \cdot Q_{G_k,\,svc}\left(\alpha_{k,\,svc}\right) \tag{13}$$

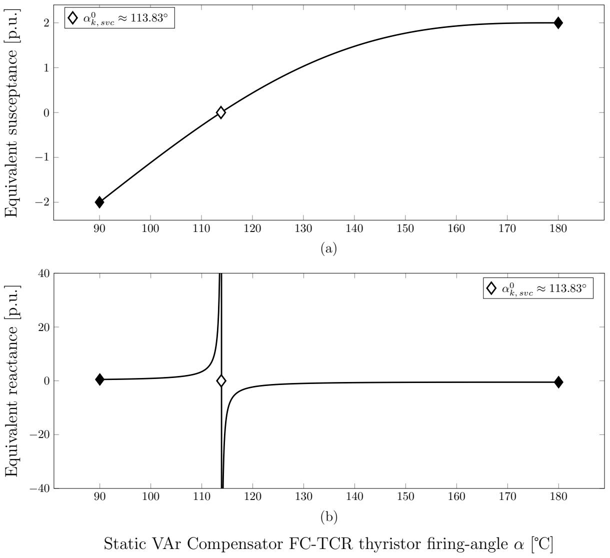

Figure 4. Static VAr Compensator (a) equivalent susceptance and (b) equivalent reactance outputs as functions of the thyristor firing-angle.

$$y = \alpha_{k,\,svc} - 90° \tag{14}$$

$$Q_{G_k,\,svc}\left(\alpha_{k,\,svc}\right) = V_{k,\,svc}^2 \cdot b_{eq}\left(\alpha_{k,\,svc}\right) \tag{15}$$

$$r = \frac{V_{m,\,svc}^{min} - V_{m,\,svc}^{max}}{Q_{G_k,\,svc}\left(180°\right) - Q_{G_k,\,svc}\left(90°\right)} \tag{16}$$

The *droop* variable "r" was introduced by Barbosa and Passos Filho (2022) as an enhancement to the traditional SVC thyristor firing-angle methodology proposed by Ambriz-Perez et al. (2000). Considering the *droop* variable, the SVC controlled bus voltage magnitude per thyristor firing-angle and per reactive power injection are illustrated by Figures 5 and 6, respectively. As detailed by the aforementioned figures, the *droop* variation directly influences the thyristor firing-angle and reactive power injection values. Adopting the *droop* values between 1% and 5% better represents the SVC steady-state operational behavior. The 0% *droop* highlighted in both figures corresponds to an ideal operational behavior for the SVC.

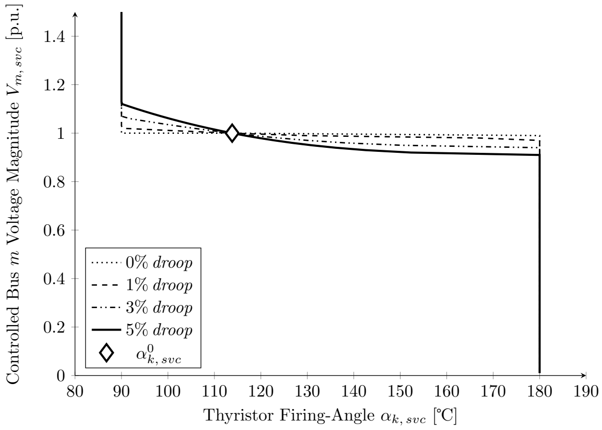

Figure 5. Static VAr Compensator controlled bus voltage magnitude per thyristor firing-angle.

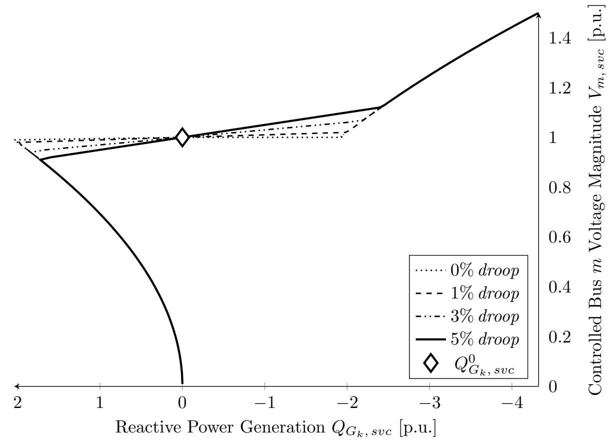

Figure 6. Static VAr Compensator controlled bus voltage magnitude per reactive power injection characteristic.

In this methodology, the SVC thyristor firing-angle ($\alpha_{k,\,svc}$) is considered the new state variable (or control variable). This methodology is well-suited for harmonics and electromagnetic transients studies (Miller et al., 1982; Ambriz-Perez et al., 2000). Additionally, the relationship between SVC's reactive power injection and thyristor firing-angle is defined by (15). By means of this equation the SVC reactive power injection and thyristor firing-angle methodologies are correlated.

2.4 Full Newton Method

The power equations that model an EPS can be summarized by (17) (Stott, 1974; Kundur, 1994):

$$\boldsymbol{f}\left(\boldsymbol{\theta}, \boldsymbol{V}\right) = \boldsymbol{0} \tag{17}$$

where $\boldsymbol{f}$ corresponds to the vector of nonlinear power equations, $\boldsymbol{\theta}$ is the vector of buses phase angle and $\boldsymbol{V}$ is the vector of buses voltage magnitude. By introducing new control equations into the set of nonlinear power equations, (17) is modified as follows:

$$\boldsymbol{f}\left(\boldsymbol{\theta}, \boldsymbol{V}, \boldsymbol{x}\right) = \boldsymbol{0} \tag{18}$$

where $\boldsymbol{x}$ corresponds to the vector of control variables. This vector dimension depends directly on the number of control equations added to the set of nonlinear power equations. The addition of new control equations ($\boldsymbol{y}$) and control variables ($\boldsymbol{x}$) to the power flow problem depicts the *full* Newton method.

By applying Newton-Raphson's numerical method, the nonlinear power equations and additional control equations ($\boldsymbol{y}$) are linearized, resulting in the following:

$$\begin{bmatrix} \Delta \boldsymbol{P} \\ \Delta \boldsymbol{Q} \\ \Delta \boldsymbol{y} \end{bmatrix} = \begin{bmatrix} \partial \boldsymbol{P}/\partial \boldsymbol{\theta} & \partial \boldsymbol{P}/\partial \boldsymbol{V} & \partial \boldsymbol{P}/\partial \boldsymbol{x} \\ \partial \boldsymbol{Q}/\partial \boldsymbol{\theta} & \partial \boldsymbol{Q}/\partial \boldsymbol{V} & \partial \boldsymbol{Q}/\partial \boldsymbol{x} \\ \partial \boldsymbol{y}/\partial \boldsymbol{\theta} & \partial \boldsymbol{y}/\partial \boldsymbol{V} & \partial \boldsymbol{y}/\partial \boldsymbol{x} \end{bmatrix} \cdot \begin{bmatrix} \Delta \boldsymbol{\theta} \\ \Delta \boldsymbol{V} \\ \Delta \boldsymbol{x} \end{bmatrix} \tag{19}$$

Within the linearization, the power and control equations, as well as the state and control variables, variation is determined. Although the SVC methodologies detailed in the previous subsections present multiple control equations, in the *full* Newton method, only the control equation that best expresses the behavior of the SVC during the power flow iterative Newton-Raphson solution process is linearized.

3. SIMULATION RESULTS

For testing and validation of the proposed methodology, two EPSs were analyzed: a 4-bus tutorial system and the IEEE benchmark Nordic system. Simulations were carried out in a developed Python-based program, and the results were validated using CEPEL's production-grade academic version software.

The proposed SVC steady-state methodologies simulation results were analyzed using positive and negative load variation in each EPS under study. In addition, the *flat start* condition was applied to initiate all simulations.

Since the SVC reactive power injection methodology is implemented at CEPEL's production-grade software, the simulations obtained by applying this methodology were used as a reference in this study.

3.1 4-Bus Tutorial system

For this case study, the EPS system topology and data are illustrated in Figure 7. The SVC is connected at a low-side bus and controls the voltage magnitude of the high-side bus directly connected to it. A ±50 MVAr range and 3% linear operation *droop* was adopted for the SVC, and the result of the simulations are shown in Tables 1, 2 and 3.

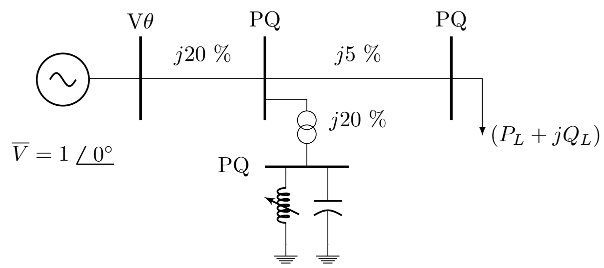

Figure 7. Static VAr Compensator controlled bus voltage magnitude per reactive power generation characteristic.

Table 1. Simulation results of the SVC reactive power injection methodology.

Simulation	$V_{m,\,svc}$ [p.u.]	Operational Region	$Q_{G_k,\,svc}$ [p.u.]	$P_L + jQ_L$ [p.u.]	Iterations
1	1.008	Linear	0.411	1.200 + j0.000	5
2	1.010	Linear	0.509	1.320 + j0.000	5
3	1.010	Linear	0.509	1.321 + j0.000	5
4	1.010	Cap.	0.510	1.322 + j0.000	5
5	1.007	Cap.	0.507	1.330 + j0.000	6
6	0.976	Cap.	0.476	1.400 + j0.000	6
7	0.992	Linear	-0.407	0.500 - j0.600	5
8	0.990	Linear	-0.476	0.500 - j0.700	4
9	0.990	Linear	-0.489	0.500 - j0.720	5
10	0.990	Ind.	-0.490	0.500 - j0.721	4
11	0.990	Ind.	-0.490	0.500 - j0.724	4
12	1.000	Ind.	-0.500	0.500 - j0.800	4

As can be observed, all SVC methodologies presented in Section 2 could correctly represent the steady-state behavior of the control device. However, the SVC thyristor firing-angle methodology, compared to the SVC reactive power injection and current injection methodologies, had considerably greater iteration counts. The higher iteration counts are clearly observed for the SVC operating in the Capacitive ($\alpha = 180°$) or Inductive ($\alpha = 90°$) regions.

Table 2. Simulation results of the SVC current injection methodology.

Simulation	$V_{m,\,svc}$ [p.u.]	Operational Region	$Q_{G_k,\,svc}$ [p.u.]	$P_L + jQ_L$ [p.u.]	Iterations
1	1.008	Linear	0.411	1.200 + j0.000	5
2	1.010	Linear	0.509	1.320 + j0.000	5
3	1.010	Linear	0.509	1.321 + j0.000	5
4	1.010	Cap.	0.509	1.322 + j0.000	5
5	1.007	Cap.	0.507	1.330 + j0.000	6
6	0.976	Cap.	0.476	1.400 + j0.000	6
7	0.992	Linear	-0.407	0.500 - j0.600	5
8	0.990	Linear	-0.476	0.500 - j0.700	4
9	0.990	Linear	-0.489	0.500 - j0.720	5
10	0.990	Ind.	-0.490	0.500 - j0.721	5*
11	0.990	Ind.	-0.490	0.500 - j0.724	4
12	1.000	Ind.	-0.500	0.500 - j0.800	4

Table 3. Simulation results of the SVC thyristor firing-angle methodology.

Simulation	$V_{m,\,svc}$ [p.u.]	Operational Region	$Q_{G_k,\,svc}$ [p.u.]	$P_L + jQ_L$ [p.u.]	Iterations
1	1.008	Linear ($\alpha = 144.24°$)	0.411	1.200 + j0.000	6*
2	1.010	Linear ($\alpha = 171.7°$)	0.509	1.320 + j0.000	10**
3	1.010	Linear ($\alpha = 174.2°$)	0.509	1.321 + j0.000	10**
4	1.010	Cap. ($\alpha = 180°$)	0.51	1.322 + j0.000	10**
5	1.007	Cap. ($\alpha = 180°$)	0.507	1.330 + j0.000	9**
6	0.976	Cap. ($\alpha = 180°$)	0.476	1.400 + j0.000	8**
7	0.992	Linear ($\alpha = 93.88°$)	-0.407	0.500 - j0.600	6*
8	0.990	Linear ($\alpha = 90.65°$)	-0.476	0.500 - j0.700	5*
9	0.990	Linear ($\alpha = 90.01°$)	-0.489	0.500 - j0.720	6*
10	0.990	Ind. ($\alpha = 90°$)	-0.490	0.500 - j0.721	10**
11	0.990	Ind. ($\alpha = 90°$)	-0.490	0.500 - j0.724	10**
12	1.000	Ind. ($\alpha = 90°$)	-0.500	0.500 - j0.800	10**

3.2 IEEE Nordic system

The Nordic system A topology, whose data is available at (Van Cutsem et al., 2015), is analyzed for this case study. The IEEE Nordic system is a medium-scale network with over 70 buses and 100 lines. The SVC is connected to bus 1041 and controls its own bus voltage magnitude. A ±200 MVAr range and 3% linear operation *droop* was adopted for the SVC, and the result of the simulations is shown in Table 4.

Table 4. Assessment of simulation results for SVC methodologies in the IEEE Nordic system.

SVC Methodology	$V_{m,\,svc}$ [p.u.]	Operational Region	$Q_{G_k,\,svc}$ [p.u.]	ΔLoad	Iterations
Reactive Power Injection	0.974	Linear	1.256	+3.5%	6
	1.012	Linear	0.004	0%	5
	1.031	Linear	-0.632	-3.5%	5
	1.103	Ind.	-2.431	-25%	5
Current Injection	0.974	Linear	1.256	+3.5%	6
	1.012	Linear	0.004	0%	5
	1.031	Linear	-0.632	-3.5%	5
	1.103	Ind.	-2.431	-25%	5
Thyristor Firing-Angle	0.974	Linear ($\alpha = 136.14°$)	1.256	+3.5%	7*
	1.012	Linear ($\alpha = 113.88°$)	0.004	0%	6*
	1.031	Linear ($\alpha = 106.24°$)	-0.632	-3.5%	6*
	1.103	Ind. ($\alpha = 90°$)	-2.431	-25%	7**

Varying the IEEE Nordic system total load by +3.5%, 0%, −3.5% and −25%, not only was it possible to observe that all presented SVC methodologies were able to represent the steady-state behavior of the control device correctly, but

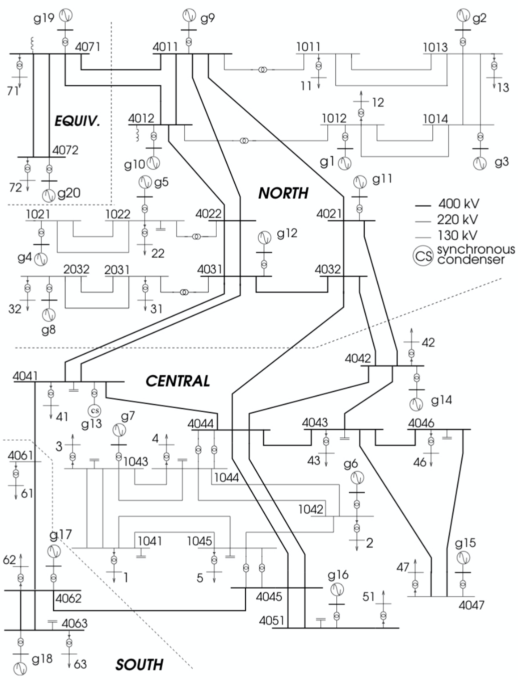

Figure 8. Nordic system A topology. Source: Van Cutsem et al. (2015).

also the number of iterations were higher when analyzing the SVC thyristor firing-angle methodology results.

4. CONCLUSION

In this work it was made a review and assessment of the main methodologies for representing SVCs steady-state behavior in the power flow problem. The proposed SVC methodologies consider the *full* Newton method, which updates, during its iterative process, the control equation that best represents the behavior of the SVC at a given operative period. This method improves the Jacobian matrix sparsity characteristic according to the number of SVCs actively operating in the EPSs analyzed.

From the results of the simulations carried out in both EPSs analyzed, it is assumed that all SVC models correctly represent the steady-state behavior of the control device in the power flow problem, despite each methodology implementation being more appropriate for different research goals.

Considering the SVC thyristor firing-angle methodology, the observed higher number of iterations is justified by the reason that the control variable $\alpha_{k,\,svc}$ tends to be more sensitive than the control variable $Q_{G_k,\,svc}$ or $I_{G_k,\,svc}$. This sensitivity can be visualized in Figure 4(a), where it is illustrated that small variations of $\alpha_{k,\,svc}$ provoke significant variations in the control device equivalent susceptance, and, consequently, in the reactive power generated by the equipment.

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