POWERFACTORY

PowerFactory 2021

Technical Reference

Thyristor-Controlled Series Compensation

ElmTcsc

PF2021

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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Contents

1 General Description

PowerFactory provides both an AC and a DC thyristor-controlled series compensation model.

2 Basic Data

Figure 2.1 shows the basic scheme of the TCSC.

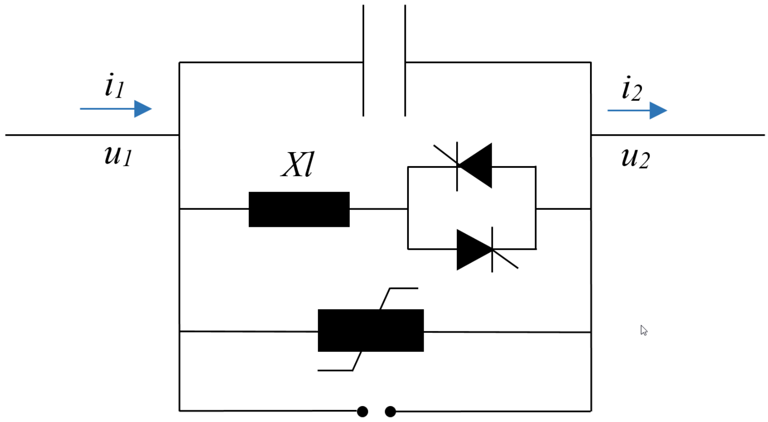

Figure 2.1: Basic Scheme

3 Load Flow Analysis

3.1 AC-Model

Typically, in load flow calculations, the controlled operation of a TCSC is modelled. The following operation modes are supported:

- Active power: see Section 3.1.1.
- Reactive power: see Section 3.1.1.
- Current magnitude: Controls the magnitude of the current value going through the TCSC.
- Effective reactance: Controls the effective reactance of the TCSC.
- Transmission angle: Controls the difference of the voltage angle at both terminals (*u:phiu:1 - u:phiu:2*).

For each of these methods, the effective reactance (X_{TCSC}) in Ohm is calculated so that following equations are satisfied:

$$\underline{u_1} - \underline{u_2} = \underline{i_1} \cdot \frac{(jX_{TCSC})}{U_{nom:1}^2} \tag{1}$$

$$\underline{i_1} + \underline{i_2} = 0 \tag{2}$$

$$actualvalue = setpoint \tag{3}$$

The values of voltage and current are in p.u. based on 1 MVA and $U_{nom:1}$.

From the effective reactance, the firing angle (α) is calculated, such that the equation 4 is satisfied.

$$\begin{aligned} X_{TCSC}(\alpha) = &- X_C + C_1\{2(\pi - \alpha) + sin[2(\pi - \alpha)]\} \\ &- C_2 cos^2(\pi - \alpha)\{k_x tan[k_x(\pi - \alpha)] - tan(\pi - \alpha)\} \end{aligned} \tag{4}$$

Where:

- Xc is the capacitor reactance
- Xl is the thyristor-controlled reactance
- $k_x = \sqrt{\frac{Xc}{Xl}}$
- $X_{LC} = \frac{Xc \cdot Xl}{Xc - Xl}$
- $C_1 = \frac{Xc + X_{LC}}{\pi}$
- $C_2 = \frac{4X_{LC}^2}{\pi Xl}$

3.1.1 Power control

The active or reactive power can be controlled at the local terminal (terminal i or terminal j can be selected), or at a remote location (remote cubicle or boundary).

When the remote location has been selected, an orientation parameter *iOrient* has to be specified. The options are the following:

- +P, +Q: At these locations, any increase in the measured power will result in more power flowing through the TCSC, which in turn will decrease the effective reactance.
- -P, -Q: At these locations, any increase in the measured power will result in less power flowing through the TCSC, which in turn will increase the effective reactance.

The figure 3.1 explains it graphically.

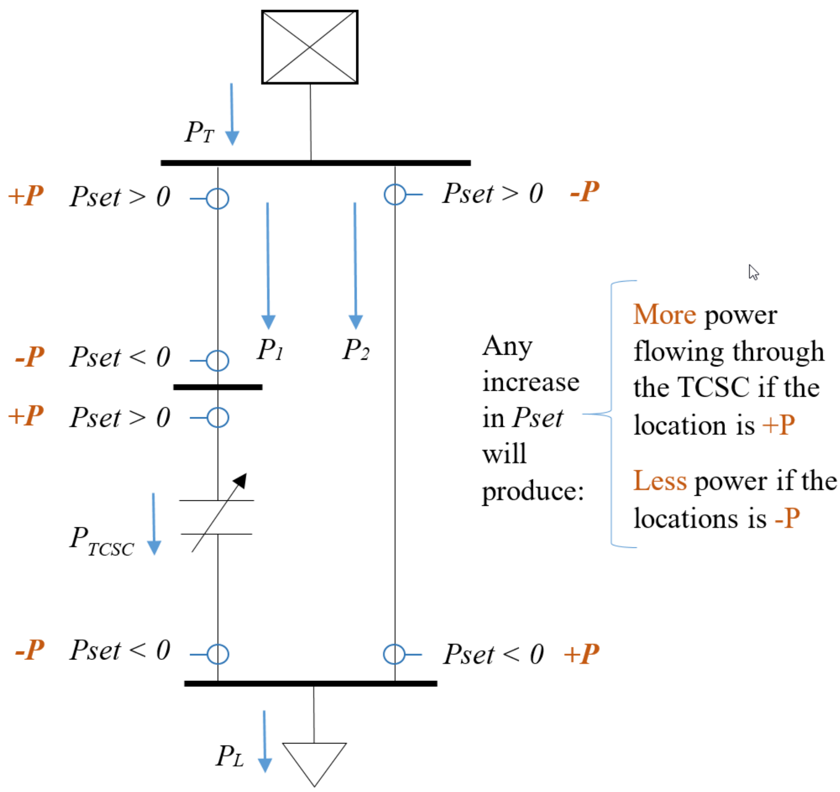

Figure 3.1: Orientation parameter

3.1.2 Limits

The limits can be specified as minimum and maximum effective reactance values. The firing angle is then calculated from the computed effective reactance during the load flow solution, within a range of 90° to 180°. If there is at least one pole within this range, then the first firing angle found will be displayed. If no firing angle value was found, then the displayed value is zero.

Alternatively, the limits can be given as minimum and maximum firing angles.In this case, the respective effective reactance limits will be calculated using equation 4. If there is at least one pole within this range, then the effective reactance limits will not be considered and the first firing angle found will be displayed. If no firing angle value was found, then the displayed value is zero.

The number of poles in the specified range are calculated by equation 5.

$$\alpha_{TCSC} = \pi \left[1 - \frac{(2n-1)\omega\sqrt{LC}}{2} \right], n = 1,2,3... \tag{5}$$

In addition, the maximum voltage drop/rise can be specified. This parameter modifies the effective reactance, so that the voltage drop/rise does not exceed the given value. The modified effective reactance will still respect the maximum/minimum reactance limits.

3.1.3 Quasi-Dynamic Simulation

For the quasi-dynamic simulation, the following input signal is available:

- XTCSCin, effective reactance in Ohm

When this signal is connected, the value is used directly in Equation 1, and disregarding Equation 3, thus disabling the specified control mode.

3.1.4 Calculation Quantities

Loading

The loading of the TCSC is calculated as follows:

$$loading = \frac{max(I_{bus1}, I_{bus2})}{I_{nom}} \cdot 100 \qquad in\ \%$$

- $loading$: Loading in %
- I_{nom} : Nominal current $= I_r$ of the TCSC in kA
- I_{bus1} : Magnitude of the current at terminal i
- I_{bus2} : Magnitude of the current at terminal j

If a thermal rating object is selected, the nominal current I_{nom} is determined as follows:

- if the continuous rating is entered in MVA:
  - 3-phase TCSC:

  $$I_{nom} = ContRating/(\sqrt{3} \cdot U_{n(bus1)})$$

  where $U_{n(bus1)}$ is the nominal voltage in kV of the connected terminal i
- if the continuous rating is entered in kA:

  $$I_{nom} = ContRating$$

- if the continuous rating is entered in %:

  $$I_{nom} = ContRating/100 \cdot I_r$$

For an unbalanced load flow calculation the highest current of all phases is used.

Losses

The losses are calculated as follows:

Quantity	Unit	Description	Value
$Ploss$	MW	Losses (total)	$= 0$
$Qloss$	$Mvar$	Reactive-Losses (total)	$= 0$
$Plossld$	MW	Losses (load)	$= 0$
$Qlossld$	$Mvar$	Reactive-Losses (load)	$= 0$
$Plossnld$	MW	Losses (no load)	$= 0$
$Qlossnld$	$Mvar$	Reactive-Losses (no load)	$= 0$

Table 3.1: Losses Quantities, AC-model

Voltage Drop

Quantity	Unit	Description	Value
du	$p.u.$	Voltage Drop	$= \lvert\underline{u}_{bus1}\rvert - \lvert\underline{u}_{bus2}\rvert$
$dupc$	$\%$	Voltage Drop	$= du \cdot 100$
$dphiu$	deg	Voltage Drop Angle	$= \phi_{u,bus1} - \phi_{u,bus2}$
$du1$	$p.u.$	Positive Sequence Voltage Drop	$= \lvert\underline{u1}_{bus1}\rvert - \lvert\underline{u1}_{bus2}\rvert$
$du1pc$	$\%$	Positive Sequence Voltage Drop	$= du1 \cdot 100$
$dphiu1$	deg	Positive Sequence Voltage Drop Angle	$= \phi_{u1,bus1} - \phi_{u1,bus2}$

Table 3.2: Voltage Drop Quantities, AC-model

u_{bus1} and u_{bus2} are the corresponding terminal voltage in p.u. based on the rated voltage of the terminal. $\phi_{u,bus1}$ and $\phi_{u,bus2}$ the terminal voltage angle in deg. For an unbalanced load flow du, $dupc$, $dphiu$ is per phase available, e.g. $c : dupc : B$.

3.2 AC-Model for DC Load Flow (linear)

For the DC load flow, only the following control methods are supported:

- Active power: see Section 3.1.1.
- Effective reactance: Controls the effective reactance of the TCSC.

For each of these methods, the effective reactance (X_{TCSC}) in Ohm is calculated so that the followings equations are satisfied:

$$(\phi_{bus1} - \phi_{bus2})/X_{rea} = P_{bus1} \tag{6}$$

$$P_{bus1} + P_{bus2} = 0 \tag{7}$$

where ϕ_{bus1} is the voltage angle on terminal i, ϕ_{bus1} angle on terminal j.

3.2.1 Power control

See Section 3.1.1.

3.2.2 Limits

See Section 3.1.2.

3.2.3 Calculation Quantities

See Section 3.1.4.

4 RMS-Simulation

Two input signals are available:

- gatea, firing angle in degrees
- XTCSC, effective reactance in Ohm

The signal *gatea* has priority over *XTCSC*. When the *gatea* is used, the effective reactance is calculated using 4 and then using equations 1 and 2.

4.1 EMT Simulation

The EMT model is described by the following equations and the Figure 4.1.

Two input signals are available:

- gatea, firing angle in degrees
- XTCSC, effective reactance in Ohm

The signal *gatea* has priority over *XTCSC*. When the *XTCSC* is used, the firing angle is calculated using 4 and then using the following equations:

$$iC\_A = c \cdot \frac{du_{C:A}}{dt} \tag{8}$$

$$\frac{diL\_A}{dt} = \begin{cases} 0 & \text{if thyristor off} \\ \frac{u_{C:A}}{l} & \text{if thyristor on} \end{cases} \tag{9}$$

$$i_{1:A} = iC\_A + iL\_A \tag{10}$$

$$i_{1:A} + i_{2:A} = 0 \tag{11}$$

The equations are the same for phases B and C.

The values of voltage and current are in p.u. based on 1 MVA and $U_{1:A}$.

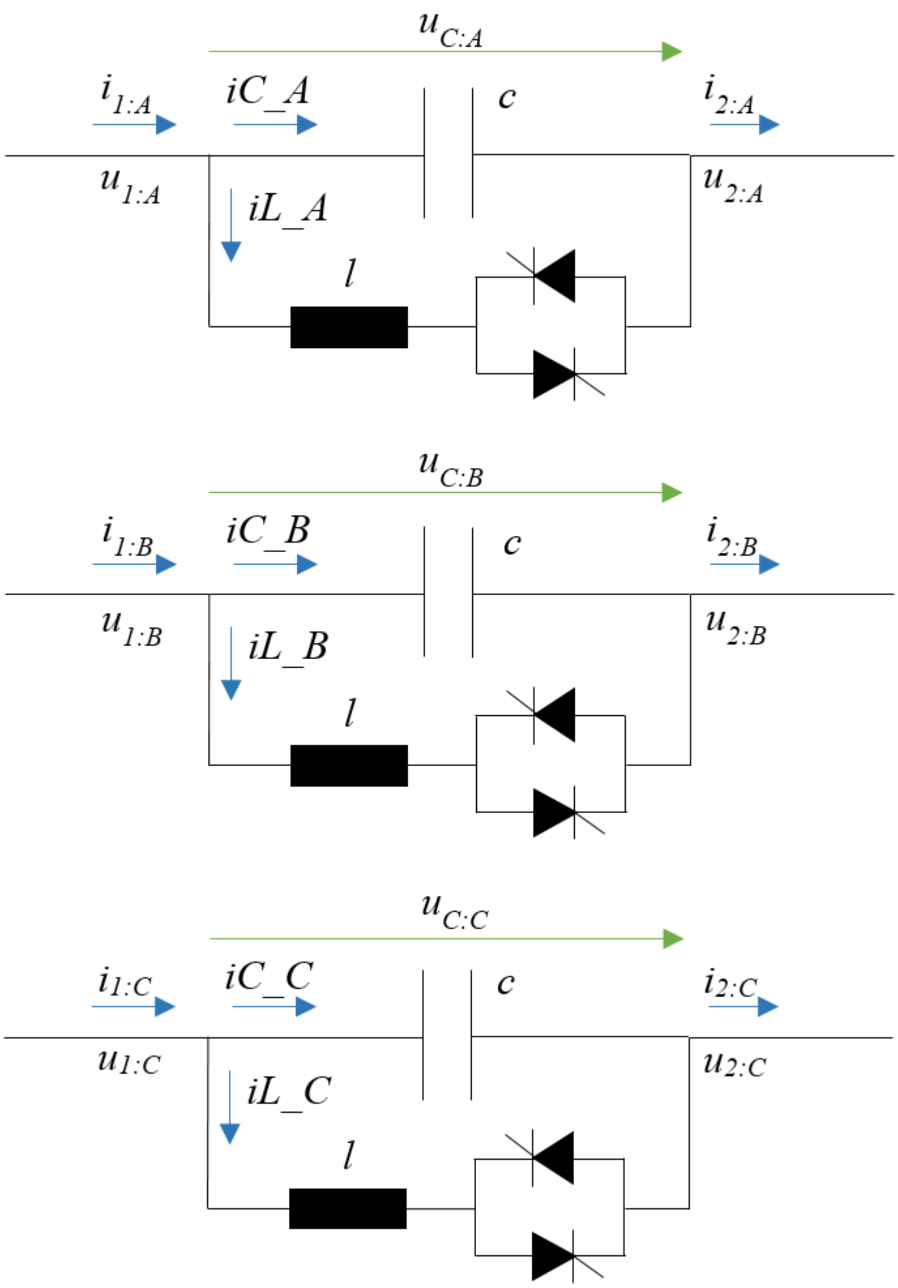

Figure 4.1: EMT Model

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