POWERFACTORY

PowerFactory 2021

Technical Reference

DC Valve

ElmValve

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

PF2021

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Contents

1 General Description

The *DC Valve* element can be used in *PowerFactory* for modelling different semiconductor devices. The element can be connected to DC terminals only. To an AC terminal it can be connected through the AC/DC connector element *ElmConnectacdc*.

Depending on the selected valve type, several different devices can be modelled as presented in Table 1.1 and shown in Figure 1.1.

Table 1.1: DC Valve models

Controllability	**Device**
Not controllable	Diode
Semi-controllable (turn-on)	Thyristor
Fully controllable (turn-on/off)	Gate Turn-Off thyristor (GTO), Integrated Gate-Commutated Thyristor (IGCT), Isolated Gate Bipolar Transistor (IGBT), ...

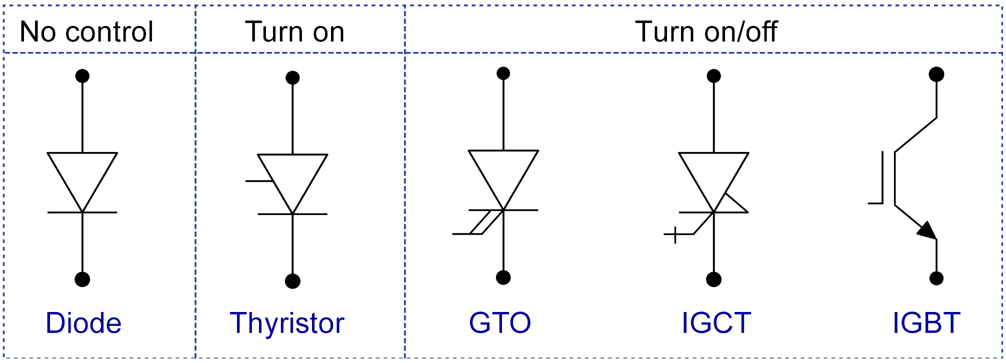

Figure 1.1: Symbol representation of the semiconductor devices

The antiparallel diode option is available for the turn-on and for the turn-on/off devices as shown for a thyristor and an IGBT in Figure 1.2.

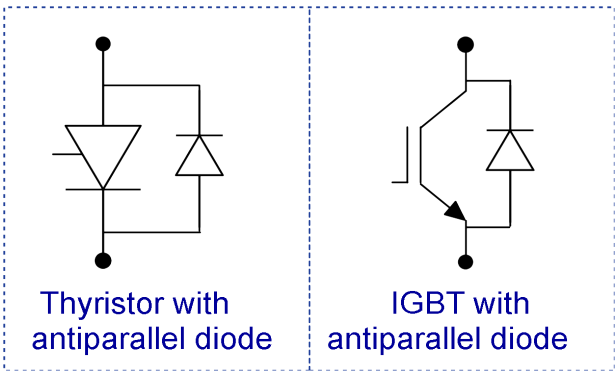

Figure 1.2: Symbol representation of the semiconductor devices with antiparallel diode

The models used in the different calculation functions are described in the following chapters.

The same load flow model is used in the balanced and in the unbalanced load flow calculation. The same dynamic model is used for the balanced/unbalanced RMS and EMT simulations.

2 Load Flow Analysis

In *Load Flow Analysis* the *DC Valve* element supports AC balanced and unbalanced calculations. The model is not considered for DC Load Flow calculations.

For the load flow analysis the model corresponds to the equivalent circuit shown in 2.1.

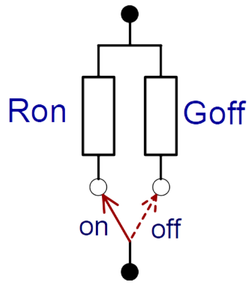

Figure 2.1: Load flow model

2.1 Model Equations

If the device is blocked, the current flows through the conductance and the following equation is valid:

$$(U_{dc1} - U_{dc2}) \cdot G_{off} = I_{dc} \tag{1}$$

and if the device is not blocked, the current flows through the resistance:

$$U_{dc1} - U_{dc2} - uthres \cdot (1 - R_{on} \cdot G_{off}) = I_{dc} \cdot R_{on} \tag{2}$$

where:

- U_{dc1}, U_{dc2} are the terminal DC voltages of the element in kV;
- I_{dc} is the DC current flowing through the element in kA;
- G_{off} is the internal conductance in S;
- R_{on} is the internal resistance in Ω;
- $uthres$ is the forward voltage in kV.

2.2 State change control

During the Load Flow calculation, the initial state of the diode can change automatically if the current gets negative or if the voltage difference gets higher then the voltage threshold (Figure 2.2). The switching to On state of the controllable devices depends also on the $fired$ input parameter of the device (Figure 2.3).

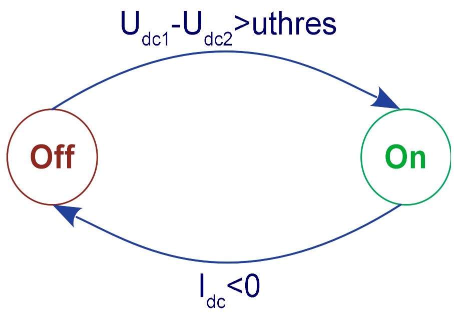

Figure 2.2: Load Flow state change of diode (not controllable)

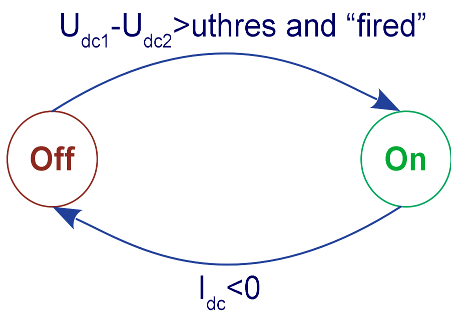

Figure 2.3: Load Flow state change of semi-controllable and fully controllable devices

2.3 Losses

The total losses for the element in MW and Mvar are obtained as:

$$\begin{aligned} Ploss &= P_{bus1} + P_{bus2} \\ Qloss &= 0 \end{aligned} \tag{3}$$

where P_{bus1} and P_{bus2} are calculation parameters available for the element.

The load losses are calculated as the difference between the total losses and the no-load losses:

$$\begin{aligned} Plossld &= Ploss - Plossnld = Ploss \\ Qlossld &= 0 \end{aligned} \tag{4}$$

where the no-load losses are $Plossnld = 0$.

3 Short Circuit Calculation

When calculating maximum DC short-circuit current, the DC Valve is neglected (it has no resistance).

When calculating the minimum DC short-circuit current, the DC Valve is taken into account having a resistance R_{on}.

4 Time domain simulation

As shown in Figure 4.1 the model for the time domain simulation is extended by a parallel snubber circuit consisting of a capacitance and conductance. The same model is valid for RMS and EMT simulations.

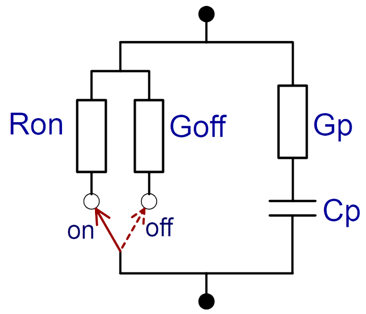

Figure 4.1: RMS and EMT simulation model

If the device is blocked, the current flows through the conductances and the following equation is valid:

$$(U_{dc1} - U_{dc2}) \cdot G_{off} + (U_{dc1} - U_{dc2} - U_c) \cdot G_p = I_{dc} \tag{5}$$

and if the device is not blocked, G_{off} is replaced with $1/R_{on}$ and equation is multiplied with R_{on} to evade division with zero:

$$(U_{dc1} - U_{dc2} - uthres \cdot (1 - R_{on} \cdot G_{off})) + (U_{dc1} - U_{dc2} - U_c) \cdot G_p \cdot R_{on} = I_{dc} \cdot R_{on} \tag{6}$$

The following equation needs to be satisfied for the capacitor voltage:

$$(U_{dc1} - U_{dc2} - U_c) \cdot G_p = C_p \cdot \frac{dU_c}{dt} \tag{7}$$

- U_{dc1}, U_{dc2} are the terminal DC voltages of the element in kV;
- U_c is the DC voltages of the parallel capacitance kV;
- I_{dc} is the DC current flowing through the element in kA;
- G_{off} is the internal conductance in S;
- R_{on} is the internal resistance in Ω;
- G_p is the internal parallel conductance of the snubber circuit in S;
- C_p is the internal parallel capacitance of the snubber circuit in F;
- $uthres$ is the forward voltage in kV.

4.1 State change control

The state change logic differs for the not controllable, semi-controllable and fully controllable devices.

The semi-controllable and fully controllable devices are controlled by the external input signal $gate$.

4.1.1 Diode (not controllable)

If the diode is conducting or not depends on the conditions presented in Figure 4.2.

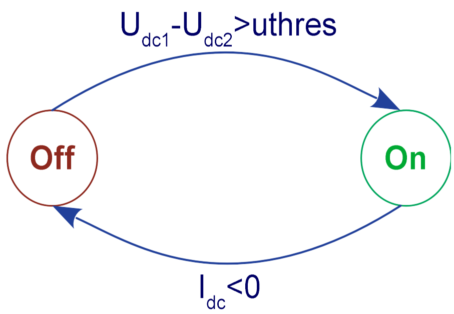

Figure 4.2: State change of diode (not controllable)

4.1.2 Thyristor (semi-controllable)

The switching to on state of the thyristors depends also on the $gate$ input signal of the device as shown in Figure 4.3.

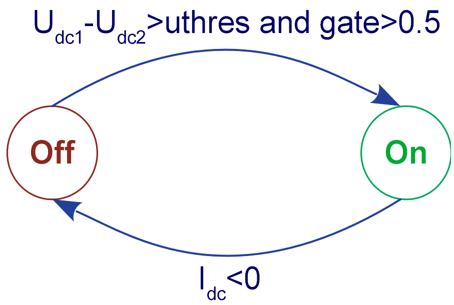

Figure 4.3: State change of thyristor(semi-controllable)

4.1.3 GTO, IGCT, IGBT (fully controllable)

The switching to on and off state of the fully controllable devices depends also on the $gate$ input signal of the device as shown in Figure 4.4.

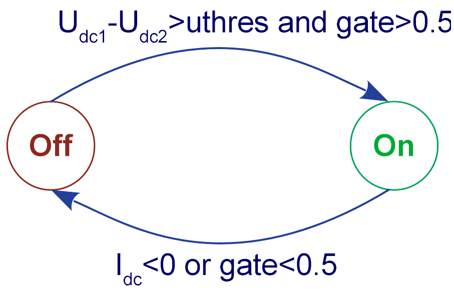

Figure 4.4: State change of thyristor(semi-controllable)

4.2 Inputs/State Variables of the Dynamic Model

Table 4.1: Input Definition of the RMS and EMT Models

Input Signal	**Symbol**	**Description**	**Unit**
gate		Gate signal for controlling the device	

Table 4.2: State Variables Definition of the RMS and EMT Models

Parameter	**Symbol**	**Description**	**Unit**
uC	U_c	Capacitance voltage	V

5 Harmonics/Power Quality

The *DC Valve* element is ignored for harmonic load flow and frequency sweep calculations.

List of Figures

List of Tables