POWERFACTORY

PowerFactory 2021

Technical Reference

DC Voltage Source

ElmDcu, ElmDcubi

PF2021

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

Publisher:
DIgSILENT GmbH
Heinrich-Hertz-Straße 9
72810 Gomaringen / Germany
Tel.: +49 (0) 7072-9168-0
Fax: +49 (0) 7072-9168-88
info@digsilent.de

Please visit our homepage at:
https://www.digsilent.de

December 1, 2020
PowerFactory 2021
Revision 1

Contents

1 General Description

The *DC Voltage Source* element is the model of a DC voltage source. The element can be connected to DC terminals only (Phase technology: DC). It is available both as a single-port and two-ports element.

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. Furthermore, the same dynamic model is used for the balanced/unbalanced RMS and EMT simulations.

2 DC Voltage Source

2.1 Load Flow Analysis

In *Load Flow Analysis* the *DC Voltage Source* 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. When the internal resistance Ri is set to zero, the DC voltage source imposes a constant DC voltage on the connected terminal and behaves as an ideal DC voltage source.

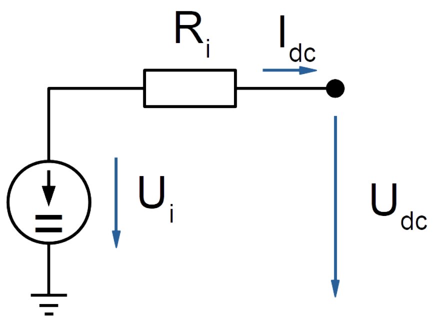

Figure 2.1: Load Flow DC Voltage Source Model

2.1.1 Model Equations

The resulting voltage of the DC voltage source is given by the following equation:

$$\begin{aligned} U_i &= uset \cdot Unom \\ U_{dc} &= U_i + I_{dc} \cdot R_i \end{aligned} \tag{1}$$

where:

- U_{dc} is the resulting DC voltage on the connected terminal in kV;
- $uset$ is the voltage setpoint in $p.u.$;
- $Unom$ is the nominal DC voltage of the element in kV;
- I_{dc} is the DC current flowing through the element in kA;
- R_i is the internal resistance in Ω.

2.1.2 Slack Assignment

The priority for the automatic slack assignment algorithm is dependent on the nominal voltage and the corresponding voltage setpoint if $uset > 0.7\ p.u.$:

$$Prio = 10^{15} \cdot U_{nom} \cdot uset$$

else if $uset \geq 1e^{-6}\ p.u.$

$$Prio = 0.001 \cdot U_{nom} \cdot uset$$

else, when used as grounding element the voltage source is not used as slack.

For the DC voltage source with two terminals the following priority is always used:

$$Prio = 10^{15} \cdot U_{nom} \cdot uset$$

2.1.3 QDSL Interface

The following input signals are available to control the voltage source via QDSL model:

- $uset$ is the voltage setpoint in $p.u.$

2.2 Short Circuit Calculation

There is no DC current contribution from the DC voltage source model to DC fault. The DC voltage source is therefore ignored in the short-circuit calculation in all short-circuit methods.

2.3 Time Domain Simulation

As shown in Figure 2.2 the model of the DC voltage source is extended by a series inductance for the time domain simulations.

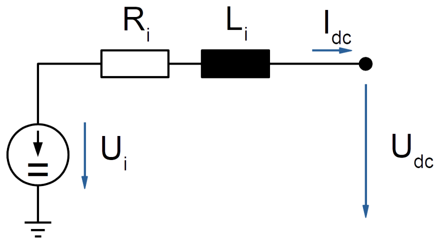

Figure 2.2: RMS and EMT DC Voltage Source Model

Hence the response of the model is given by the following differential equation:

$$
\begin{aligned}
U_i &= uset \cdot Unom \\
U_{dc} &= U_i + I_{dc} \cdot R_i + L_i \cdot 1000 \cdot \frac{dI_{dc}}{dt}
\end{aligned} \tag{2}
$$

where:

- U_{dc} is the resulting DC voltage on the connected terminal in kV;
- $uset$ is the voltage setpoint input signal in $p.u.$;
- $Unom$ is the nominal DC voltage of the element in kV;
- I_{dc} is the DC current flowing through the element in kA;
- R_i is the internal resistance in Ω.
- L_i is the internal inductance in mH.

For dynamic studies it is possible to externally control the desired voltage on the DC terminal by using the $uset$ input signal.

2.3.1 Inputs to the Dynamic Model

Table 2.1: Input Definition of the RMS and EMT Models

Input Signal	Symbol	Description	Unit
uset		DC voltage setpoint	p.u.

2.4 Harmonics/Power Quality

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

3 DC Voltage Source with Two Terminals

3.1 Load Flow Analysis

In *Load Flow Analysis* the *DC Voltage Source with Two Terminals* element supports AC balanced and unbalanced calculations. The model is not considered for DC Load Flow calculations.

The equivalent circuit of the DC voltage source with two terminals is shown in 3.1. The difference to the model with one terminal is that the DC voltage (U_{dc}) is actually the DC voltage difference between the two DC terminals $U_{dc} = \Delta U_{dc} = U_{dc,bus1} - U_{dc,bus2}$.

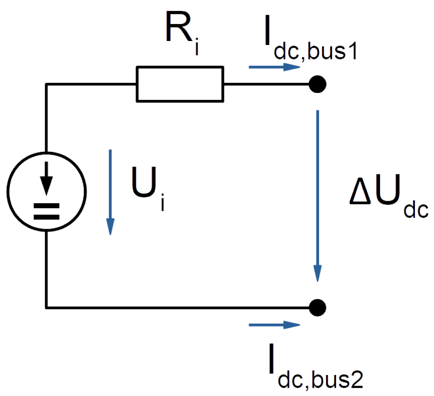

Figure 3.1: Load Flow DC Voltage Source with Two Terminals Model

3.1.1 Model Equations

The resulting voltage of the DC voltage source is given by the following equation:

$$\begin{aligned} U_i &= uset \cdot Unom \\ \Delta U_{dc} &= U_i + I_{dc,bus1} \cdot Ri \\ I_{dc,bus1} + I_{dc,bus2} &= 0 \end{aligned} \tag{3}$$

where:

- ΔU_{dc} is the DC voltage difference between the two DC terminals ($\Delta U_{dc} = U_{dc,bus1} - U_{dc,bus2}$) in kV;
- $uset$ is the voltage setpoint in $p.u.$;
- $Unom$ is the nominal DC voltage of the element in kV;
- $I_{dc,bus1}$ is the DC current at terminal *bus1* flowing through the element in kA;
- $I_{dc,bus2}$ is the DC current at terminal *bus2* flowing through the element in kA;
- R_i is the internal resistance in Ω.

3.2 Short Circuit Calculation

The *DC Voltage Source with Two Terminals* is ignored for the short circuit calculation.

3.3 Time Domain Simulation

As shown in Figure 3.2 the model of the *DC voltage source with Two Terminals* is extended by a series inductance for the time domain simulations. The difference to the model with one terminal is that the (U_{dc}) is actually the DC voltage difference between the two DC terminals $U_{dc} = \Delta U_{dc} = U_{dc,bus1} - U_{dc,bus2}$.

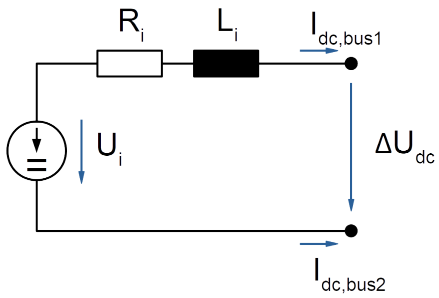

Figure 3.2: RMS and EMT DC Voltage Source with Two Terminals Model

Hence the response of the model is given by the following differential equation:

$$
\begin{aligned}
U_i &= uset \cdot Unom \\
\Delta U_{dc} &= U_i + I_{dc,bus1} \cdot Ri + Li \cdot 1000 \cdot \frac{dI_{dc,bus1}}{dt} \\
I_{dc,bus1} + I_{dc,bus2} &= 0
\end{aligned}
\tag{4}
$$

where:

- ΔU_{dc} is the DC voltage difference between the two DC terminals ($\Delta U_{dc} = U_{dc,bus1} - U_{dc,bus2}$) in kV;
- $uset$ is the voltage setpoint input signal in $p.u.$;
- $Unom$ is the nominal DC voltage of the element in kV;
- $I_{dc,bus1}$ is the DC current at terminal *bus1* flowing through the element in kA;
- $I_{dc,bus2}$ is the DC current at terminal *bus2* flowing through the element in kA;
- R_i is the internal resistance in Ω.
- L_i is the internal inductance in mH.

For dynamic studies it is possible to externally control the desired voltage on the DC terminal by using the $uset$ input signal.

3.3.1 Inputs to the Dynamic Model

Table 3.1: Input Definition of the RMS and EMT Models

Input Signal	Symbol	Description	Unit
uset		DC voltage setpoint	p.u.

3.4 Harmonics/Power Quality

The *DC voltage source with Two Terminals* element is ignored for harmonic load flow and frequency sweep calculations.

List of Figures

List of Tables