POWERFACTORY

PowerFactory 2021

Technical Reference

Battery

ElmBattery, ElmBatterybi

PF2021

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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Contents

1 General Description

This document describes the models of the DC Battery *ElmBattery* and the DC Battery with two terminals *ElmBatterybi*.

These elements are based on the model of a DC voltage source element (*ElmDcu*). The Battery element can be connected to DC terminals only (Phase technology: DC).

2 Battery

Figure 2.1 depicts the equivalent circuit of the model composed of an ideal DC voltage source and an output impedance.

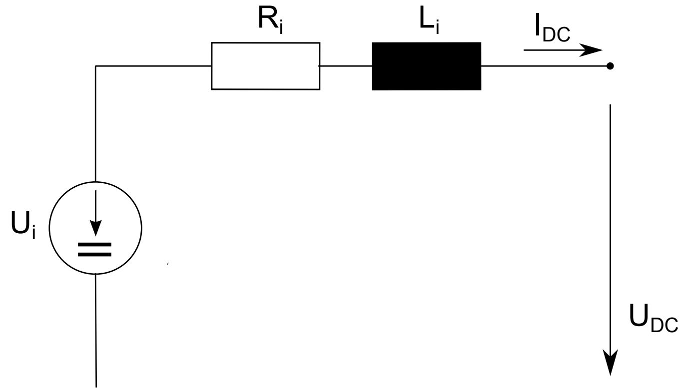

Figure 2.1: DIgSILENT Battery Model

2.1 Load Flow Analysis

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

2.1.1 Model Equations

For AC balanced and unbalanced *Load Flow Analysis* the internal inductance L_i of the battery model is ignored, therefore only the internal resistance R_i is considered. The internal voltage is kept constant as described in the equations below:

$$U_i = U_{nom} \cdot uset \tag{1}$$
$$U_{DC} = U_i - I_{DC} \cdot R_i \tag{2}$$

where:

- U_i is the internal voltage in $[kV]$;
- U_{nom} is the nominal voltage of the battery in $[kV]$;

- $uset$ is the voltage setpoint in $[p.u.]$;
- R_i is the internal resistance in $[Ohm]$;
- I_{DC} is the DC current in $[kA]$;
- U_{DC} is the DC voltage in $[kV]$.

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

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

For the battery model with two terminals the following priority is always used:

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

2.1.3 Calculation Parameters

The following calculation parameters are available for *Load Flow Analysis*:

Table 2.1: Calculation parameters (Load Flow Analysis)

Variable	Unit	Description	Symbol
$Unom$	kV	Nominal Voltage	U_{nom}
$uset$	p.u.	Voltage Setpoint	$uset$
ri	p.u.	Internal Resistance	r_i
$iRefElement$		Reference Element	

where r_i in p.u. is defined as shown below:

$$r_i = R_i \cdot \frac{1}{Un^2}$$

and Un is the rated voltage in $[kV]$ of the corresponding connected terminal.

The parameter $iRefElement$ is set to 1 if the battery is marked as “Slack” for the DC system.

2.1.4 QDSL Interface

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

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

2.2 Short Circuit Analysis

The battery model is considered only for DC short-circuit calculation.

2.2.1 DC Short Circuit

The DC short-circuit calculation considers the battery as a DC source which contributes to the total fault current. From the aspects of the international standards it is being described in the IEC 61660 and in the ANSI/IEEE 946.

For the DC short-circuit calculation the nominal voltage can be entered in an alternative manner:

$$U_{nom} = cellnum \cdot cellvol$$

The internal resistance is defined as below:

$$R_i = cellnum \cdot cellres$$

The internal inductance is defined as below:

$$L_i = cellnum \cdot cellind$$

where:

- $cellnum$ is the number of cells;
- $cellvol$ is the cell nominal voltage in [kV];
- $cellres$ is the resistance per cell in [Ohm];
- $cellind$ is the inductance per cell in [mH];

The operational voltage depends on the DC short-circuit standard chosen. E_B is set to:

- for IEC 61660 method to $E_B = f_B \cdot U_{nom}$
- for ANSI 946\IEEE method to $E_B = U_{nom}$

IEC 61660
The quasi steady-state short-circuit current is calculated using equation (3) and is usually taken as the current one second after the fault has occurred.

$$I_{kB} = \frac{0.95 \cdot E_B}{R_{BBr} + 0.1 \cdot R_B} \tag{3}$$

The peak short-circuit current is calculated as in equation (4).

$$i_{pB} = \frac{E_B}{R_{BBr}} \tag{4}$$

The time to peak t_{pB} and the rise-time constant τ_{1B} depend on the $\frac{1}{\delta}$ and are shown on the Figurefig:fig10.

$$\frac{1}{\delta} = \frac{2}{\frac{R_{BBr}}{L_{BBr}} + \frac{1}{T_B}} \tag{5}$$

Figure 2.2 shows the time constants as provided in the Figure 10. of the IEC 61660:1997 standard.

The battery time constant is taken as fixed $T_B = 30\,ms$. The decay-time constant is $\tau_{2B} = 100\,ms$.

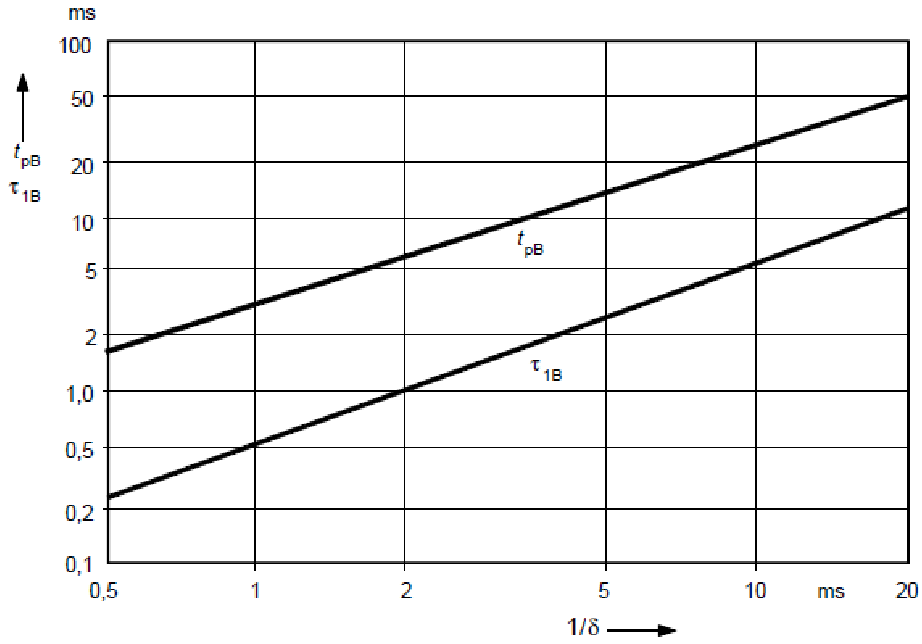

Figure 2.2: Time to peak t_{pB} and rise-time constant τ_{2B}

ANSI/IEEE 946

If the internal resistance is set to 0, then a default value is calculated as shown in equation (6).

$$R_B = \frac{E_B}{100 \cdot I_{8hrs}} \tag{6}$$

The maximum short-circuit current and the quasi steady-state current are described in equation (7).

$$I_{kB} = i_{pB} = \frac{E_B}{R_{BBr}} \tag{7}$$

The initial rate of rise of the short-circuit current is described in equation (8).

$$RR = \frac{E_B}{L_{BBr}} \tag{8}$$

The battery time constant is calculated based on equation (9).

$$T_B = \frac{L_{BBr}}{R_{BBr}} \tag{9}$$

Calculation Parameters

The following calculation parameters are available:

Table 2.2: Calculation parameters (DC Short Circuit)

Variable	Unit	Description
U_{nom}	kV	Operational System Voltage
E_B	kV	Operational Battery Voltage
R_B	Ohm	Battery Resistance
L_B	mH	Battery Inductance
R_{BBr}	Ohm	Branch Resistance (up to the fault location)
L_{BBr}	mH	Branch Inductance (up to the fault location)
δ	1/s	Decay coefficient (for IEC 61660)
T_B	s	Battery time-constant
t_{pB}	ms	Time to peak (for IEC 61660)
τ_{1B}	ms	Rise-time constant (for IEC 61660)
τ_{2B}	ms	Decay-time constant (for IEC 61660)
f_B		Battery voltage coefficient (for IEC 61660)
i_{pB}	kA	Peak short-circuit current
I_{kB}	kA	Quasi steady-state short-circuit current
RR	kA/s	Rate of rise (for ANSI/IEEE)

R_{BBr} is the internal battery resistance added to the resistance of the line to the fault location.

$$R_{BBr} = R_B + R_{Br} \tag{10}$$

L_{BBr} is the internal battery inductance added to the inductance of the line to the fault location.

$$L_{BBr} = L_B + L_{Br} \tag{11}$$

2.3 Time Domain Simulation

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

$$\begin{aligned} U_i &= U_{nom} \cdot uset \\ U_{DC} &= U_i + I_{DC} \cdot Ri + Li \cdot 1000 \cdot \frac{dI_{DC}}{dt} \end{aligned} \tag{12}$$

where:

- U_i is the internal voltage in kV;
- U_{nom} is the nominal voltage of the battery in kV;
- $uset$ is the voltage setpoint input signal in $p.u.$;
- R_i is the internal resistance in Ohm;
- L_i is the internal inductance in mH;
- I_{DC} is the DC current in kA;
- dI_{DC}/dt is the derivative of the DC current in kA/s;
- U_{DC} is the DC voltage in kV.

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 Calculation Parameters

The following calculation parameters are available:

Table 2.3: Calculation parameters

Parameter	Unit	Description
$Unom$	kV	Nominal Voltage
ri	p.u.	Internal Resistance
li	p.u.	Internal Inductance

where ri and li in p.u. are defined as follows:

$$ri = R_i \cdot \frac{1}{Un^2}$$
$$li = \frac{L_i}{1000} \cdot \frac{1}{Un^2}$$

and Un represents the rated voltage in kV of the corresponding connected terminal.

2.3.2 Signals

The following signals are available:

Table 2.4: *ElmBattery* Signals

Parameter	Unit	IN/OUT	Description
$uset$	p.u.	IN	Voltage Setpoint

2.4 Harmonics/Power Quality

The Battery element is ignored for harmonic load flow and frequency sweep calculations.

2.5 Optimal Power Flow

The model equations described in Section 2.1 apply for *Optimal Power Flow*.

3 Battery with Two Terminals

Figure 3.1 depicts the equivalent circuit of the model with two terminals, composed of an ideal DC voltage source and an output impedance.

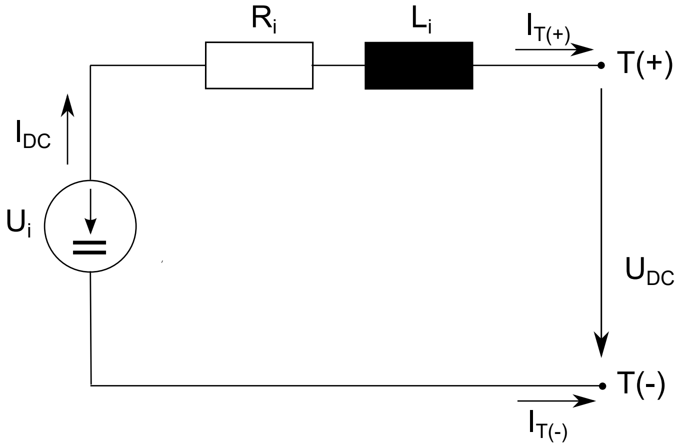

Figure 3.1: DIgSILENT Battery Model with Two Terminals

3.1 Load Flow Analysis

In *Load-Flow Analysis* the *Battery with two terminals* element supports AC balanced and unbalanced calculations. The model is not considered for DC Load Flow calculations.

3.1.1 Model Equations

The models described in section 2.1 are also valid for the two-terminal model. The only difference is the calculation of the dc voltage and current, which are considered as follows:

$$U_{DC} = U_{T(+)} - U_{T(-)} \tag{13}$$
$$I_{DC} = I_{T(+)} + I_{T(-)} \tag{14}$$

3.2 Short Circuit Analysis

The battery with two terminals is ignored for the short circuit calculation.

3.3 Time Domain Simulation

The models described in section 2.3 are also valid for the two-terminal model.

The DC voltage (U_{DC}) is:

$$U_{DC} = U_{T(+)} - U_{T(-)}$$

and the following additional equation is fulfilled:

$$I_{DC} = I_{T(+)} + I_{T(-)}$$

3.4 Harmonics/Power Quality

The battery with two terminals is ignored for the harmonics calculation.

3.5 Optimal Power Flow

The models described in Section 2.5 are also valid for the two-terminal model.

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