POWERFACTORY

PowerFactory 2021

Technical Reference

AC Current Source

ElmIac, ElmIacbi

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

PF2021

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

January 26, 2021
PowerFactory 2021
Revision 2

Contents

1 General Description

This document describes the AC current Source *ElmIac* and the AC current Source with two terminals *ElmIacbi*.

The AC Current Source model can be used to represent a current injection in the system. It should be connected to three phase AC terminals, as it does not support two phase and single phase systems. The current source can be used for balanced and unbalanced calculations and can be useful for:

- Wind turbine modelling
- HVDC system modelling
- Photovoltaic modelling
- Injection of harmonic currents in the system
- General circuit analysis

2 Load Flow Analysis

Figure 2.1 shows the positive, negative and zero sequence circuit diagram of the AC current source.

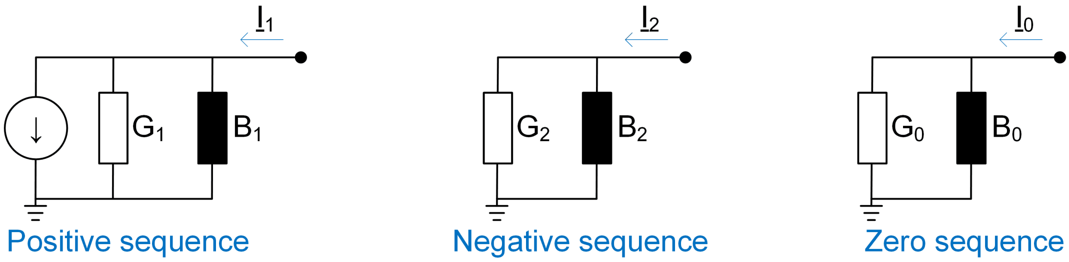

Figure 2.1: AC current source sequence models

Figure 2.2 shows the positive, negative and zero sequence circuit diagram of the AC current source with two terminals.

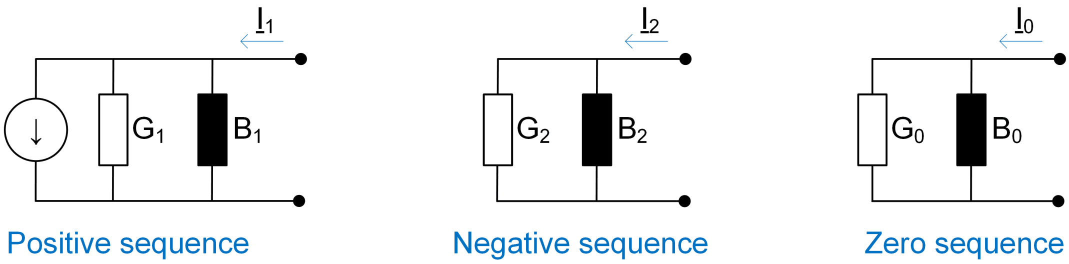

Figure 2.2: Two terminal AC current source sequence models

In contrast with the AC voltage source where it is possible to define negative and zero sequence voltages, in the AC current source the current injection can be controlled only in the positive sequence (for both balanced and unbalanced models). For the negative and zero sequence currents, the internal admittances in the negative and zero sequence are considered.

The positive sequence equation is defined with an apparent power equation as:

$$\underline{S}_{1setp} = \sqrt{3} \cdot \underline{U}_1 \cdot (\underline{I}_1 - (G_1 + \jmath B_1) \cdot \underline{U}_1)^* \tag{1}$$

where the set-point apparent power is:

$$\underline{S}_{1setp} = \sqrt{3} \cdot isetp \cdot Ir \cdot |\underline{U}_1| \cdot (\cos(phiui) + \jmath \sin(phiui)) \tag{2}$$

In terms of the positive sequence current, Equation 1 is equivalent to:

$$\underline{I}_1 = \underline{I}_{1setp} + (G_1 + \jmath B_1) \cdot \underline{U}_1 \tag{3}$$

where the setpoint current is:

$$\underline{I}_{1setp} = isetp \cdot Ir \cdot \frac{|\underline{U}_1|}{\underline{U}_1^*} \cdot (\cos(phiui) + \jmath \sin(phiui)) \tag{4}$$

The negative and zero sequence equations for the unbalanced calculation are defined as:

$$\underline{I}_0 = \underline{U}_0 \cdot G_0 + \jmath\, \underline{U}_0 \cdot B_0 \tag{5}$$

$$\underline{I}_2 = \underline{U}_2 \cdot G_2 + \jmath\, \underline{U}_2 \cdot B_2 \tag{6}$$

In the above equations, $\underline{U}_1$, $\underline{U}_2$ and $\underline{U}_0$ are the sequence voltages of the connected terminal and $isetp$, I_r, G_1, B_1, G_2, B_2, G_0 and B_0 are the input parameters.

The angle $phiui$ is defined through the power factor $cosini$ as:

$$phiui = \begin{cases} \arccos(cosini) & \text{if pf is inductive} \\ -\arccos(cosini) & \text{if pf is capacitive} \end{cases} \tag{7}$$

The current setpoint $isetp$ can be defined as a negative value to generate/inject power.

For the two terminal AC current source, the equations are similar where same equations are valid where the sequence voltages are replaced by the difference in voltage between the two terminals $\Delta\underline{U}_1 = \underline{U}_{1,bus1} - \underline{U}_{1,bus2}$ and the corresponding $\Delta\underline{U}_0$ and $\Delta\underline{U}_2$. The angle between voltage and current $phiui$ is based on the voltage and current of connection $bus1$.

2.1 QDSL Interface

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

- $i0$ is the Current Input in $p.u.$
- $phiui$ is the Angle-Input (u,i) in rad

If the signal $i0$ is connected the current set-point $isetp$ is replaced by the input signal (see equation (1)).

3 Short-Circuit Analysis

For VDE/IEC and ANSI short-circuit calculation there is no defined short-circuit contribution for AC current sources.

In the Complete Short-Circuit Method data of the internal conductance and susceptance for positive, negative and zero sequence are needed. The *ElmIac* and *ElmIacbi* behave as a constant current source for symmetrical faults. For unsymmetrical faults, they behave as a constant current source in the positive sequence network and as a constant admittance in the negative and zero sequence networks.

4 Harmonic Load Flow

The AC current source can be used to define harmonic current injections into the network. To define the harmonics it is possible to select a spectrum which contains the harmonic currents. For more information regarding how to define a spectrum refer to User's Manual "Definition of Harmonic Injections". The harmonic current can be referred to either the fundamental or rated current and it can be chosen between Balanced, Unbalanced and according to IEC61000 representation.

5 Frequency Sweep

In the frequency sweep calculation the internal current of the current source is set to $0A$ and $0deg$ (open-circuit). The parameter *Spectral Density of the Current Magnitude/Angle* ($didf, d\phi df$ in p.u./Hz, deg/Hz) and the corresponding frequency dependent characteristic allows for the definition of an internal current according to equations (8) and (9).

$$i_i(\omega_h) = didf \cdot i_{char}(\omega_h) \tag{8}$$

$$\phi_{Ii}(\omega_h) = d\phi df \cdot \phi_{I,char}(\omega_h) - \Delta\phi_{Ii} \tag{9}$$

where:

$$\Delta\phi_{Ii} = \phi_{Ii} - \phi_{Iref} \tag{10}$$

$didf$ and $d\phi df$ are constant input parameters used to scale the frequency characteristics i_{char} and $\phi_{I,char}$ in (8). The characteristics can be either polynomial (using the *PowerFactory ChaPol* object) or a vectorial characteristic (using the *ChaVec* object) with a frequency scale (using the *TriFreq* object). The angle $\Delta\phi_{Ii}$ accounts for the angle deviation between the current and the system reference voltage angle.

A common application is the analysis of the transfer function of a part of the system or the propagation of a current impulse in frequency domain. To do this, the amplitude and phase of the spectrum current can be defined and using the frequency sweep function, the voltage at the remote end can be calculated.

6 Dynamic Simulation

For dynamic simulation, two different models can be distinguished depending on the connected input signals.

The models are described in the following subsections. For balanced RMS simulation only the positive sequence equations are used.

The capacitances used in the RMS and EMT model are obtained by dividing the input susceptances by $2 \cdot \pi \cdot F_{nom}$ where F_{nom} is the nominal system frequency in Hz.

6.1 RMS Simulation

In the RMS simulation, depending on the connected input signals, there are two ways to control the current amplitude, angle and frequency of the current source.

The angle $phii$ is used in both models and its derivative changes if there is a frequency change:

$$\frac{\mathrm{d}phii}{\mathrm{dt}} = \begin{cases} 2 \cdot \pi \cdot F_n \cdot (f0 - f_{ref}) & \text{if input signal f0 is connected} \\ 2 \cdot \pi \cdot F0Hz - 2 \cdot \pi \cdot Fnom \cdot f_{ref} & \text{if input signal F0Hz is connected} \\ 0 & \text{if it is the reference element} \end{cases} \tag{11}$$

where $f0$ and $F0Hz$ are input signals and $Fnom$ is the nominal frequency in Hz. Note that the signal f_{ref} is automatically connected to the reference machine.

For the two terminal current source, similar as in the load flow calculation, the sequence voltages need to be replaced by the difference of the sequence voltages at the two terminals: $\underline{U}_1 = \Delta\underline{U}_1$, $\underline{U}_2 = \Delta\underline{U}_2$ and $\underline{U}_0 = \Delta\underline{U}_0$.

6.1.1 Input signal $i0$ or $I0$ is connected

The positive sequence current set-point is calculated depending which of the input signals is connected:

$$\underline{I}_{1setp} = \begin{cases} i0 \cdot I_r \cdot e^{i \cdot (phii + dphii)} & \text{if input signal i0 is connected} \\ I0 \cdot e^{i \cdot (phii + dphii)} & \text{if input signal I0 is connected} \end{cases} \tag{12}$$

where I_r is the rated current of the current source and $phii$ is current angle input signal.

The positive sequence current behind the internal admittance is controlled, the resulting current depends on the admittance value and on the voltage the element is connected to. The main equations that need to be satisfied, are:

$$\begin{aligned} \underline{I}_1 &= \underline{I}_{1setp} + (G_1 + \jmath\, 2 \cdot \pi \cdot F_{nom} \cdot C_1) \cdot \underline{U}_1 \\ \underline{I}_2 &= (G_2 + \jmath\, 2 \cdot \pi \cdot F_{nom} \cdot C_2) \cdot \underline{U}_2 \\ \underline{I}_0 &= (G_0 + \jmath\, 2 \cdot \pi \cdot F_{nom} \cdot C_0) \cdot \underline{U}_0 \end{aligned} \tag{13}$$

Only positive sequence current can be controlled ($\underline{i}_{2setp}$ and $\underline{i}_{0setp}$ are zero).

6.1.2 Input signals I_A, I_B and I_C are connected

This model can be used to independently control magnitude and phase of the A, B and C current components.

If the input signals I_A, I_B and I_C are connected, the complex currents $\underline{I}_A$, $\underline{I}_B$ and $\underline{I}_C$ are calculated as follows:

$$\begin{aligned}\underline{I}_A &= I\_A \cdot e^{i \cdot phi_A}\\ \underline{I}_B &= I\_B \cdot e^{i \cdot phi_B}\\ \underline{I}_C &= I\_C \cdot e^{i \cdot phi_C}\end{aligned} \tag{14}$$

The angle for phase A ($phiA$) can be configured with the input signal $dphii$ (in rad) as:

$$phi_A = phii + dphii \tag{15}$$

For the angles of phases B and C, two additional signals are available. The angles are relative to the angle of phase A:

$$\begin{aligned}phi_B &= phi_A + phii\_B \cdot \frac{\pi}{180^\circ}\\ phi_C &= phi_A + phii\_C \cdot \frac{\pi}{180^\circ}\end{aligned} \tag{16}$$

If the two angle signals $phii\_B$ and $phii\_C$ are not connected, *PowerFactory* uses a 120° shift to calculate the two angles:

$$\begin{aligned}phi_B &= phi_A - 120^\circ \cdot \frac{\pi}{180^\circ}\\ phi_C &= phi_A + 120^\circ \cdot \frac{\pi}{180^\circ}\end{aligned} \tag{17}$$

The setpoint currents $\underline{I}_{1setp}$, $\underline{I}_{2setp}$ and $\underline{I}_{0setp}$ are obtained from the complex currents $\underline{I}_A$, $\underline{I}_B$ and $\underline{I}_C$ by using the symmetrical component transformation. The resulting currents are:

$$\begin{aligned}\underline{I}_1 &= \underline{I}_{1setp} + (G_1 + \jmath\, 2 \cdot \pi \cdot F_{nom} \cdot C_1) \cdot \underline{U}_1\\ \underline{I}_2 &= \underline{I}_{2setp} + (G_2 + \jmath\, 2 \cdot \pi \cdot F_{nom} \cdot C_2) \cdot \underline{U}_2\\ \underline{I}_0 &= \underline{I}_{0setp} + (G_0 + \jmath\, 2 \cdot \pi \cdot F_{nom} \cdot C_0) \cdot \underline{U}_0\end{aligned} \tag{18}$$

6.1.3 No signals connected

If no input signals are connected, the model is equivalent to the model described in Section 6.1.1 using the input signal $I0$. This is possible since all input signals (also $I0$) of the RMS simulation are initialised from the results provided by the Load Flow calculation.

6.1.4 Initialisation and control

The state variable $phii$ is initialised to the value of the initial angle of bus voltage $b : phiini$ (basic data parameter available for the connected terminal).

The additional angle $dphii$ is initialised as the difference between the angle of the setpoint current $\underline{I}_{1setp}$ (Equation 13) and $phii$.

Only positive sequence current can be controlled ($\underline{i}_{2setp}$ and $\underline{i}_{0setp}$ are zero).

The angle difference can be controlled using the input signal $dphii$. If a specific value ϕ_{set} is desired, then $dphii = \phi_{set} - phii$, where $phii$ changes only if the frequency at the connection terminal changes.

6.2 EMT Simulation

Very similar as in the RMS simulation, the EMT model being used depends on the connected signals and there are two ways to control the current amplitude, angle and frequency of the current source.

The two available EMT models transform the phase voltages available from the EMT simulation to $\alpha\beta\gamma$ components.

The angle $phii$ (state variable) is used in both of the models and its derivative is changed if there is a frequency change:

$$\frac{\mathrm{d}phii}{\mathrm{dt}} = \begin{cases} 2 \cdot \pi \cdot F_n \cdot f0 & \text{if input signal f0 is connected} \\ 2 \cdot \pi \cdot F0Hz & \text{if input signal F0Hz is connected} \end{cases} \tag{19}$$

where $f0$ and $F0Hz$ are input signals and F_n is the nominal frequency in Hz.

For two terminal current source, the voltages and voltage derivatives need to be replaced by the difference of the voltages and voltage derivatives at the two terminals.

6.2.1 Input signal $i0$ or $I0$ is connected

The α and β setpoint currents are calculated depending which of the input signals is connected:

$$\underline{I}_{\alpha\beta setp} = \begin{cases} i0 \cdot I_r \cdot e^{i \cdot (phii + dphii)} & \text{if input signal i0 connected} \\ I0 \cdot e^{i \cdot (phii + dphii)} & \text{if input signal I0 connected} \end{cases} \tag{20}$$

where I_r is the rated current of the current source and $phii$ is current angle input signal.

For the EMT model, the following equations are valid:

$$\begin{aligned} \underline{I}_{\alpha\beta} &= \underline{I}_{\alpha\beta setp} + G_1 \cdot \underline{U}_{\alpha\beta} + C_1 \cdot \frac{d\,\underline{U}_{\alpha\beta}}{dt} \\ I_\gamma &= G_0 \cdot U_\gamma + C_0 \cdot \frac{d\,U_\gamma}{dt} \end{aligned} \tag{21}$$

where $\underline{U}_{\alpha\beta} = U_\alpha + \jmath \cdot U_\beta$ and U_γ are the $\alpha\beta\gamma$ components of the terminal voltage.

The angle phii

6.2.2 Input signals I_A, I_B and I_C are connected

For calculating the set-points, the input signals I_A, I_B and I_C are internally first transformed to $\alpha\beta$ values $\underline{I}_{input\alpha\beta}$. The set-points are then obtained as:

$$\begin{aligned} \underline{I}_{\alpha\beta setp} &= \underline{I}_{input\alpha\beta}/\sqrt{2} \\ I_{\gamma setp} &= (I\_A + I\_B + I\_C)/3/\sqrt{2} \end{aligned} \tag{22}$$

The resulting currents for the current source are:

$$\begin{aligned} \underline{I}_{\alpha\beta} &= \underline{I}_{\alpha\beta setp} + G_1 \cdot \underline{U}_{\alpha\beta} + C_1 \cdot \frac{d\,\underline{U}_{\alpha\beta}}{dt} \\ I_{\gamma} &= I_{\gamma setp} + G_0 \cdot U_{\gamma} + C_0 \cdot \frac{d\,U_{\gamma}}{dt} \end{aligned} \tag{23}$$

6.2.3 No signals connected

If no input signals are connected, the model is equivalent to the model described in Section 6.2.2. This is possible since all input signals of the EMT simulation are initialised from the results provided by the Load Flow calculation.

6.2.4 Initialisation

The state variable $phii$ is initialised to the value of the initial angle of bus voltage $b:phiini$ (basic data parameter available for the connected terminal).

The additional angle $dphii$ is initialised as the difference between the angle of the setpoint current $\underline{I}_{1setp}$ (Equation 13) and $phii$.

6.3 Input/Output signals definition

The use of input and output signals from the dynamic model shown in Figure 6.1 could be used to control the current injection into a system. This is useful to model a current impulse source or to define a lightning current standard model.

With the help of a composite model and using a Fourier source *ElmFsrc* harmonic currents can be injected during an EMT simulation. For more information please refer to Fourier Source Technical Reference.

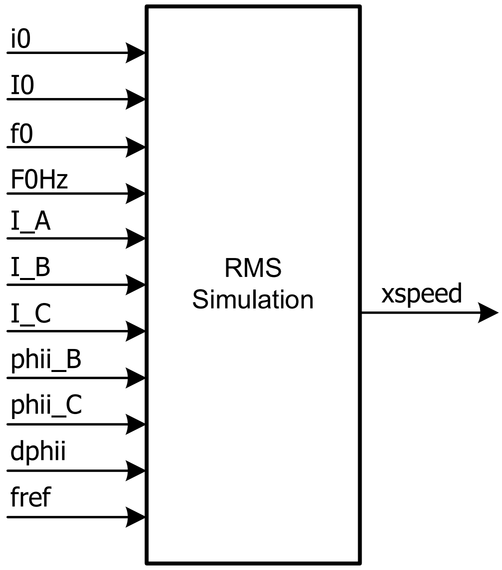

Figure 6.1: Input/Output Definition of AC Current Source (RMS-Simulation)

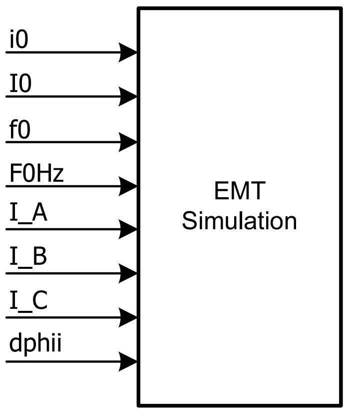

Figure 6.2: Input/Output Definition of AC Current Source (EMT-Simulation)

A Signal Definitions

Table A.1: Input/Output signals

Name	Description	Unit	Type	Model
i0	Current-Input	p.u.	IN	RMS, EMT
I0	Current-Input	kA	IN	RMS, EMT
f0	Frequency-Input	p.u.	IN	RMS, EMT
F0Hz	Frequency-Input	Hz	IN	RMS, EMT
I_A	Current, Magnitude	kA	IN	RMS, EMT
I_B	Current, Magnitude	kA	IN	RMS, EMT
I_C	Current, Magnitude	kA	IN	RMS, EMT
phii_B	Current, Angle, Phase b	deg	IN	RMS
phii_C	Current, Angle, Phase c	deg	IN	RMS
dphii	Additional Angle	rad	IN	RMS, EMT
fref	Reference Frequency	p.u.	IN	RMS
xspeed	Frequency	p.u.	OUT	RMS

List of Figures

List of Tables