POWERFACTORY

PowerFactory 2021

Technical Reference

Current Measurement

StaImea

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POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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1 General Description

The *Current Measurement Device* (*StaImea*) can be used to measure the current flow at a cubicle of any element, which is connected to a terminal/busbar. The measured current can then be fed into a controller. The reference "Measurement Location" defines the cubicle at which the current is measured. If no measurement location is set, the current measurement element should be placed inside a cubicle, which then defines automatically the measured location.

The direction (sign) of the current flow is depending on the element and its connection point. For loads, motors and passive elements (lines, transformers, etc.) the current flow is always defined in load orientation (in the direction of the active power flow). This means the current is always flowing out of the terminal into the element. For sources, e.g. generators, external network, current and voltage sources, etc... the current is in generator orientation and thus out of the element in the direction to the connected bus.

AC, DC and BI-phase system types can be measured by the *StaImea* element. Also, *Number of phases* option is available in the *StaImea*:

- if *Number of phases* $=3$, not only three-phase, but also two-phase and single-phase elements can be measured (the non-relevant outputs are then set to 0).
- if *Number of phases* = 1, the measured quantities *a, b, c or n* can be selected by the appropriate *Measured Phase*.

The outputs of the measurement device can be selected to be phase or transformed quantities:

- *Phase quantities*, depending on the selection of the *p.u. values* three different options are available:
  - *Equivalent to kA values*, where the $p.u.$ output value corresponds to the value in kA,
  - *Based on current rating of connected element* where the $p.u.$ output is based on current rating of the connected element, and
  - *Based on user-defined current* where the $p.u.$ output has is calculated using the $Inom$ input parameter as base value.
- *Transformed quantities*, depending on the selection of the *p.u. values* there are three different options:
  - *Based on 1 MVA and nominal voltage*, where the $p.u.$ output is based on $1kA$,
  - *Based on current rating of connected element* where the $p.u.$ output is based on current rating of the connected element, and
  - *Based on user-defined current* where the $p.u.$ output has is calculated using the $Inom$ input parameter as base value.

The current magnitudes (i, $i2$, $i0$, ...) are calculated by using the real and imaginary part of the corresponding current as follows:

$$i = \sqrt{ir^2 + ii^2} \tag{1}$$

If an element and its controller models are using an A-stable integration algorithm, the connected measurement device should also use this algorithm, thus the flag '*iAstabint*' on the RMS-simulation page should be selected.

The output signals and transformation equations of the *StaImea* element are documented in the following sections.

2 RMS-Simulation

The equations for balanced and unbalanced RMS simulation are described in the following subsections.

2.1 Balanced

From the balanced RMS-Simulation, the real and imaginary part of the positive-sequence current are available. Based on these currents, also additional current quantities can be calculated.

2.1.1 Phase quantities outputs

The available measurement outputs are presented in Table 2.1.

Table 2.1: Phase quantities outputs for Balanced RMS-Simulation

Name	**Unit**	**Type**	**Description**
$i1r$	$p.u.$	Output	Positive sequence current, real Part
$i1i$	$p.u.$	Output	Positive sequence current, imaginary Part

- For DC systems, only one signal is available $i1r$ ($i1i = 0$).

2.1.2 Transformed quantities outputs

The available outputs for a measurement at a single terminal are presented in Table 2.2.

Table 2.2: Transformed quantities outputs for Balanced RMS-Simulation

Name	**Unit**	**Type**	**Description**
ir	$p.u.$	Output	Positive sequence current, real part
ii	$p.u.$	Output	Positive sequence current, imaginary part
i	$p.u.$	Output	Positive sequence current, magnitude

- For DC systems, only one signal is available ir ($ii = 0$).

2.2 Unbalanced

From the unbalanced RMS-Simulation, the real and imaginary parts of the line-ground current ($\underline{u}_a$, $\underline{u}_b$ and $\underline{u}_c$) are available to the measurement device. Using these available currents, also additional quantities like the positive-, negative-, and zero-sequence currents can be calculated.

The unbalanced measurement depends on the *No. of Phases* option (parameter $nphase$).

2.2.1 Phase quantities outputs

The available measurement outputs are presented in Table 2.3.

Table 2.3: Phase quantities outputs for Unbalanced RMS-Simulation

Name	Unit	Type	Description
ir_A	$p.u.$	Output	Current, phase a, real part
ii_A	$p.u.$	Output	Current, phase a, imaginary part
ir_B	$p.u.$	Output	Current, phase b, real part
ii_B	$p.u.$	Output	Current, phase b, imaginary part
ir_C	$p.u.$	Output	Current, phase c, real part
ii_C	$p.u.$	Output	Current, phase c, imaginary part

2.2.1.1 Single-phase measurement (***Number of phases***$=1$)

The available measurement outputs are presented in Table 2.4.

Table 2.4: Phase quantities outputs for Unbalanced RMS-Simulation, single-phase measurement

Name	Unit	Type	Description
ir	$p.u.$	Output	Phase current, real part
ii	$p.u.$	Output	Phase current, imaginary part

2.2.2 Transformed quantities outputs

In the case of a three-phase system, the Transformed quantities outputs are the real and imaginary parts and magnitude of the positive-, negative- and zero-sequence current that are calculated using the symmetrical components transformation. Similar transformation is being used for the two-phase system (modal components transformation).

The available measurement outputs are presented in Table 2.5.

Table 2.5: Transformed quantities outputs for Unbalanced RMS-Simulation

Name	Unit	Type	Description
ir	$p.u.$	Output	Positive sequence current, real part
ii	$p.u.$	Output	Positive sequence current, imaginary part
i	$p.u.$	Output	Positive sequence current, magnitude
$i2r$	$p.u.$	Output	Negative sequence current, real part
$i2i$	$p.u.$	Output	Negative sequence current, imaginary part
$i2$	$p.u.$	Output	Negative sequence current, magnitude
$i0r$	$p.u.$	Output	Zero sequence current, real part
$i0i$	$p.u.$	Output	Zero sequence current, imaginary part
$i0$	$p.u.$	Output	Zero sequence current, magnitude

The output currents for three-phase unbalanced RMS simulation are calculated depending on the phase technology of the element as follows:

- 3-phase system (using symmetrical components transformation)

$$ir + j\,ii = \frac{1}{3} \cdot \left(\underline{i}_a + \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2} \right) \cdot \underline{i}_b + \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2} \right) \cdot \underline{i}_c \right) \tag{2}$$

$$i2r + j\,i2i = \frac{1}{3} \cdot \left(\underline{i}_a + \left(-\frac{1}{2} + j\frac{\sqrt{3}}{2} \right) \cdot \underline{i}_b + \left(-\frac{1}{2} - j\frac{\sqrt{3}}{2} \right) \cdot \underline{i}_c \right) \tag{3}$$

$$i0r + j\,i0i = \frac{1}{3} \cdot (\underline{i}_a + \underline{i}_b + \underline{i}_c) \tag{4}$$

- BI-phase system ($180°$):

$$ir + j\,ii = \frac{1}{2} \cdot (\underline{i}_a - \underline{i}_b) \tag{5}$$

$$i2r + j\,i2i = 0 \tag{6}$$

$$i0r + j\,i0i = \frac{1}{2} \cdot (\underline{i}_a + \underline{i}_b) \tag{7}$$

- 2-phase system ($120°$):

$$ir + j\,ii = \frac{1}{\sqrt{3}} \cdot (\underline{i}_a - \underline{i}_b) \tag{8}$$

$$i2r + j\,i2i = 0 \tag{9}$$

$$i0r + j\,i0i = \frac{1}{\sqrt{3}} \cdot (\underline{i}_a + \underline{i}_b) \tag{10}$$

- Single-phase (*Number of phases*$= 3$):

  The current is set (transformation is not used) to the complex current $\underline{i}$ available from the RMS-Simulation as follows:

$$ir + j\,ii = \underline{i} \tag{11}$$

- For DC systems, only one signal is available ir ($ii = 0$).

2.2.2.1 Single-phase measurement (*Number of phases*$= 1$)

The available outputs for a single-phase measurement (*Number of phases*$= 1$) are presented in Table 2.6.

Table 2.6: Transformed quantities outputs for Unbalanced RMS-Simulation, single-phase measurement

Name	Unit	Type	Description
ir	$p.u.$	Output	Current, real part
ii	$p.u.$	Output	Current, imaginary part
i	$p.u.$	Output	Current, magnitude

- Single-phase measurement (*Number of phases*$= 1$):

  The current is set (transformation is not used) to the complex current $\underline{i}$ available from the RMS-Simulation for the selected measured phase (*a, b, c, or n*) as follows:

$$ir + j\,ii = \underline{i} \tag{12}$$

3 EMT-Simulation

From the EMT-Simulation, the line-ground currents (i_a, i_b and i_c) are available to the measurement device. Using these currents, additional quantities like the alpha, beta and gamma components of the current can be calculated.

The output signals available for the EMT-Simulation are described in the following subsections.

3.1 Phase quantities outputs

The available measurement outputs are presented in Table 3.1.

Table 3.1: Phase quantities outputs for EMT-Simulation

Name	Unit	Type	Description
i_A	$p.u.$	Output	Current, phase a
i_B	$p.u.$	Output	Current, phase b
i_C	$p.u.$	Output	Current, phase c

3.1.1 Single-phase measurement (***Number of phases***$= 1$)

The available outputs for a single-phase measurement are presented in Table 3.2.

Table 3.2: Phase quantities outputs for EMT-Simulation, single-phase measurement

Name	Unit	Type	Description
i	$p.u.$	Output	Phase current

3.2 Transformed quantities outputs

In the case of the EMT-Simulation, the Transformed quantities outputs signals are the alpha, beta and gamma current components that are calculated using the Clarke transformation.

The available measured outputs are presented in Table 3.3.

Table 3.3: Transformed quantities outputs for EMT-Simulation, single terminal

Name	Unit	Type	Description
ir	$p.u.$	Output	Current, alpha-component
ii	$p.u.$	Output	Current, beta-component
i	$p.u.$	Output	Current, magnitude (using the alpha and beta component)
$i0$	$p.u.$	Output	Current, gamma-component

A symmetrical three-phase current with an RMS-value of $1kA$ (peak value of $\sqrt{2}\ kA$) will result in a current with a magnitude of $\sqrt{ir + ii} = 1p.u.$, assuming a rated current of $1kA$. Hence, the output of RMS- and EMT-simulation is compatible, which is important for models that shall be used in both simulation modes.

The output currents for the EMT simulation are calculated depending on the phase technology of the terminal as follows:

- 3-phase system:

  The phase currents are transformed using the $\alpha\beta\gamma$ transformation:

$$ir = i_\alpha = \frac{1}{3} \cdot (2 \cdot i_a - i_b - i_c) \tag{13}$$

$$ii = i_\beta = \frac{1}{3} \cdot (\sqrt{3} \cdot i_b - \sqrt{3} \cdot i_c) \tag{14}$$

$$i0 = i_\gamma = \frac{1}{3} \cdot (i_a + i_b + i_c) \tag{15}$$

- BI-phase system ($180°$):

$$ir = \frac{1}{2} \cdot (i_a - i_b) \tag{16}$$

$$ii = 0 \tag{17}$$

$$i0 = \frac{1}{2} \cdot (i_a + i_b) \tag{18}$$

- 2-phase system ($120°$):

$$ir = \frac{1}{\sqrt{3}} \cdot (i_a - i_b) \tag{19}$$

$$ii = 0 \tag{20}$$

$$i0 = \frac{1}{\sqrt{3}} \cdot (i_a + i_b) \tag{21}$$

- Single-phase (*Number of phases*$= 3$):

  The current is set (transformation is not used) to the current i available from the EMT-Simulation as follows:

$$ir = iu \tag{22}$$

$$ii = 0 \tag{23}$$

$$i0 = 0 \tag{24}$$

- For DC systems, only one signal is available ir ($ii = 0$, $i0 = 0$).

3.2.0.1 Single-phase measurement (*Number of phases*$= 1$)

The available outputs for a single-phase measurement (*Number of phases*$= 1$) are presented in Table 3.4.

Table 3.4: Transformed quantities outputs for EMT-Simulation, single-phase measurement

Name	Unit	Type	Description
ir	$p.u.$	Output	Current
ii	$p.u.$	Output	Current (set to 0)
i	$p.u.$	Output	Current, magnitude

- Single-phase measurement (*Number of phases*$= 1$):

  The current is set (transformation is not used) to the current i_{phase} available from the EMT-Simulation for the selected measured phase (*a, b, c, or n*) as follows:

$$ir = i_{phase} \tag{25}$$

$$ii = 0 \tag{26}$$

List of Tables