DIgSILENT

POWERFACTORY

PowerFactory 2021

Technical Reference

Common Result Variables for Terminals and Elements

EMT Simulation

PF2021

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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1 General Description

This document describes the common variables available for monitoring in *PowerFactory* for the terminals and for the single- and multiple-port elements (primary equipment). These are the parameters which are not specific to a certain element, that can be selected to be displayed in the result boxes, in the flexible data page of the elements or can be plotted in the virtual instruments.

Variables starting with capital letters are expressed in absolute values and variables starting with a lower case letters are expressed in per unit values. However for the EMT simulation there are few exceptions for the frequency related variables.

1.1 Terminals

For the terminals (*ElmTerm*) only the set *Currents, Voltages and Powers* displays common result variables that can be monitored after a calculation. The identification name of a result variable contains the letter m to denominate that it is a common monitoring variable (in opposite to c which stands for calculation variable), a semicolon and the name of the variable. For example, the result variable *Positive-Sequence Voltage, Magnitude* has the following identification name $m{:}u1$.

For the unbalanced representation, the phase result variables get a slightly different identification name where the name of the phase is added. For example: $m{:}u{:}A$.

1.2 Elements (single and multiple port)

For the single- and multiple-port elements (ex.: *ElmSym*, *ElmLne*, *ElmTr3*, etc.), there are two sets containing common result variables that can be monitored after a calculation:

- *Currents, Voltages and Powers*
- *Bus Results*

1.2.1 Currents, Voltages and Powers

The identification name of the variables available in this set is similar to the one used for the terminals with the difference that for the elements also the connection point name is added.

For example $m{:}i1{:}\_LOCALBUS$ is the magnitude of the positive-sequence current of the connected element. If the result variable is shown for a certain type of an element, the real connection point name is used. For example $m{:}i1{:}bushv$ is the magnitude of the positive-sequence current flowing through the HV connection of a transformer and $m{:}i1{:}busi$ is the magnitude of the positive-sequence current flowing through the connection '$busi$' of a line.

For the unbalanced representation, the phase result variables get a slightly different identification name where the name of the phase is added. For example: $m{:}i1{:}\_LOCALBUS{:}A$, $m{:}i1{:}bushv{:}\ A$, $m{:}I{:}bus1{:}A$.

The result variables available for the elements in $p.u.$ values are based on the element (not on the terminal). Due to this, the same variable for a port element and a terminal may have a different value. For example, if the nominal voltage of an element differs from the nominal voltage of a terminal, the positive sequence voltage magnitude $m{:}u$ will have a different value compared to $m{:}u$ of a terminal.

1.2.2 Bus Results

The result variables available in the *Bus Results* set for the terminals are actually the variables from the connected terminal i.e. they are the same as the variables available in the *Currents, Voltages and Powers* set from the terminals.

There are two differences regarding the identification name:

- the letter 'n' is used to denominate that this is a node (terminal) variable
- the connection-point name is also used

The result variables in $p.u.$ values from this set are based on the terminal. Please note that if for example for a certain element $n{:}u1{:}bus1$ and $m{:}u1{:}bus1$ are displayed, the result will be different if the nominal voltage of the element differs from the nominal voltage of the terminal.

2 EMT simulation

Voltages and currents are represented in the EMT simulation by their instantaneous values.

2.1 Result variables for terminals

As described in Section 1.2.2, the result variables from the *Bus Results* set from the port elements are equivalent to the result variables from the *Currents, Voltages and Currents* set for the terminals.

The result variables available for terminals after an EMT simulation are presented in the following sub chapters.

2.1.1 Phase voltage related variables for terminals

The voltage related variables for the terminals are all based on the phase voltages u_A, u_B and u_C resulting from the EMT simulation. The relationship between the absolute and per unit value voltage is $U_A = u_A \cdot U_{base}$ where the base voltage is $U_{base} = \sqrt{2} \cdot uknom/\sqrt{3}$ where $uknom$ is the nominal line to line voltage of the terminal.

Table 2.1: Phase voltage related variables for terminals

Name	Unit	Description
$u{:}A$	$p.u.$	Phase Voltage
$u{:}B$	$p.u.$	Phase Voltage
$u{:}C$	$p.u.$	Phase Voltage
$upc{:}A$	$\%$	Phase Voltage
$upc{:}B$	$\%$	Phase Voltage
$upc{:}C$	$\%$	Phase Voltage
$U{:}A$	kV	Phase Voltage
$U{:}B$	kV	Phase Voltage
$U{:}C$	kV	Phase Voltage

The result variables from Table 2.1 are calculated as follows:

- $u{:}A$, $u{:}B$, $u{:}C$ are the results from the EMT simulation:

$$u{:}A = u_A$$
$$u{:}B = u_B$$
$$u{:}C = u_C$$

- $upc{:}A$, $upc{:}B$, $upc{:}C$ are obtained as:

$$upc{:}A = u{:}A \cdot 100$$
$$upc{:}B = u{:}B \cdot 100$$
$$upc{:}C = u{:}C \cdot 100$$

- $U{:}A$, $U{:}B$, $U{:}C$ are obtained as:

for AC terminals $(120°)$:

$$U{:}A = \sqrt{2} \cdot u{:}A \cdot uknom/\sqrt{3}$$
$$U{:}B = \sqrt{2} \cdot u{:}B \cdot uknom/\sqrt{3}$$
$$U{:}C = \sqrt{2} \cdot u{:}C \cdot uknom/\sqrt{3}$$

for AC/BI terminals $(180°)$:

$$U{:}A = \sqrt{2} \cdot u{:}A \cdot uknom/2$$
$$U{:}B = \sqrt{2} \cdot u{:}B \cdot uknom/2$$
$$U{:}C = \sqrt{2} \cdot u{:}C \cdot uknom/2$$

where $uknom$ is the nominal voltage of the terminal.

2.1.2 Line to line voltage related variables for terminals

The line to line voltages are calculated as the difference between the two phases:
for AC terminals $(120°)$:

$$u_{lA} = (u_A - u_B)/\sqrt{3}$$
$$u_{lB} = (u_B - u_C)/\sqrt{3}$$
$$u_{lC} = (u_C - u_A)/\sqrt{3}$$

for AC/BI terminals $(180°)$:

$$u_{lA} = (u_A - u_B)/2$$
$$u_{lB} = (u_B - u_C)/2$$
$$u_{lC} = (u_C - u_A)/2$$

For a system containing two phases only the corresponding voltage phase difference is available (u_{lA} or u_{lB} or u_{lC}).

For single phase systems, the line to line voltages are not available (cannot be calculated).

Table 2.2: Line to line voltage related variables for terminals

Name	Unit	Description
$ul{:}A$	$p.u.$	Line to Line Voltage
$ul{:}B$	$p.u.$	Line to Line Voltage
$ul{:}C$	$p.u.$	Line to Line Voltage
$ulpc{:}A$	$\%$	Line to Line Voltage
$ulpc{:}B$	$\%$	Line to Line Voltage
$ulpc{:}C$	$\%$	Line to Line Voltage
$Ul{:}A$	kV	Line to Line Voltage
$Ul{:}B$	kV	Line to Line Voltage
$Ul{:}C$	kV	Line to Line Voltage

The result variables from Table 2.2 are calculated as follows:

- $ul{:}A$, $ul{:}B$, $ul{:}C$ are obtained as:

$$ul{:}A = u_{lA}$$
$$ul{:}B = u_{lB}$$
$$ul{:}C = u_{lC}$$

- $ulpc{:}A$, $ulpc{:}B$, $ulpc{:}C$ are obtained as:

$$ulpc{:}A = ul{:}A \cdot 100$$
$$ulpc{:}B = ul{:}B \cdot 100$$
$$ulpc{:}C = ul{:}C \cdot 100$$

- $Ul{:}A$, $Ul{:}B$, $Ul{:}C$ are obtained as:

$$Ul{:}A = \sqrt{2} \cdot ul{:}A \cdot uknom$$
$$Ul{:}B = \sqrt{2} \cdot ul{:}B \cdot uknom$$
$$Ul{:}C = \sqrt{2} \cdot ul{:}C \cdot uknom$$

  where $uknom$ is the nominal voltage of the terminal.

2.1.3 Line to neutral voltage related variables for terminals

The line to neutral voltages are calculated as the difference between the phase and neutral voltages:

$$u_{lnA} = u_A - u_n$$
$$u_{lnB} = u_B - u_n$$
$$u_{lnC} = u_C - u_n$$

Table 2.3: Line to neutral voltage related variables for terminals

Name	Unit	Description
$uln{:}A$	$p.u.$	Line-Neutral Voltage
$uln{:}B$	$p.u.$	Line-Neutral Voltage
$uln{:}C$	$p.u.$	Line-Neutral Voltage
$Uln{:}A$	kV	Line-Neutral Voltage
$Uln{:}B$	kV	Line-Neutral Voltage
$Uln{:}C$	kV	Line-Neutral Voltage

If no neutral connection exists the values of the variables from Table 2.3 are set to zero. If neutral connection exists, the result variables are calculated as follows:

- $uln{:}A$, $uln{:}B$, $uln{:}C$ are the magnitudes of the line to line voltages:

$$uln{:}A = u_{lnA}$$
$$uln{:}B = u_{lnB}$$
$$uln{:}C = u_{lnC}$$

- $Uln{:}A$, $Uln{:}B$, $Uln{:}C$ are obtained as:
  for AC terminals with neutral ($120°$):

$$Uln{:}A = \sqrt{2} \cdot uln{:}A \cdot uknom/\sqrt{3}$$
$$Uln{:}B = \sqrt{2} \cdot uln{:}B \cdot uknom/\sqrt{3}$$
$$Uln{:}C = \sqrt{2} \cdot uln{:}C \cdot uknom/\sqrt{3}$$

for AC/BI terminals with neutral ($180°$):

$$Uln{:}A = \sqrt{2} \cdot uln{:}A \cdot uknom/2$$
$$Uln{:}B = \sqrt{2} \cdot uln{:}B \cdot uknom/2$$
$$Uln{:}C = \sqrt{2} \cdot uln{:}C \cdot uknom/2$$

where $uknom$ is the nominal voltage of the terminal.

2.1.4 Short circuit variables for terminals

If a short circuit event is defined at the terminal, the short circuit currents I_{shcA}, I_{shcB} and I_{shcC} can be monitored by these variables.

Table 2.4: Short circuit variables for terminals

Name	Unit	Description
$Ishc{:}A$	kA	Short-Circuit Current
$Ishc{:}B$	kA	Short-Circuit Current
$Ishc{:}C$	kA	Short-Circuit Current
$ishc{:}A$	$p.u.$	Short-Circuit Current
$ishc{:}B$	$p.u.$	Short-Circuit Current
$ishc{:}C$	$p.u.$	Short-Circuit Current

The result variables from Table 2.4 are calculated as follows:

- $Ishc{:}A$, $Ishc{:}B$, $Ishc{:}C$ are the short circuit currents available from the EMT simulation:

$$Ishc{:}A = I_{shcA}$$
$$Ishc{:}B = I_{shcB}$$
$$Ishc{:}C = I_{shcC}$$

- $ishc{:}A$, $ishc{:}B$, $ishc{:}C$ are obtained as:

$$ishc{:}A = \frac{Ishc{:}A}{\sqrt{2} \cdot I_{nom\_1MVA}}$$
$$ishc{:}B = \frac{Ishc{:}B}{\sqrt{2} \cdot I_{nom\_1MVA}}$$
$$ishc{:}C = \frac{Ishc{:}C}{\sqrt{2} \cdot I_{nom\_1MVA}}$$

where $I_{nom\_1MVA} = \dfrac{1}{\sqrt{3} \cdot uknom}$ is the nominal current for $1MVA$ and $uknom$ is the nominal voltage of the connected terminal.

2.1.5 $\alpha\beta\gamma$ components and neutral voltage related variables for terminals

In addition to the phase, line to line and line to neutral voltage quantities, also $\alpha\beta\gamma$ components are available.

To project the phase quantities to a stationary reference frame the $\alpha\beta\gamma$ transformation is being used. This transformation (also called the Clarke transformation) is used for transferring the three phase instantaneous values available from the EMT simulation to $\alpha\beta\gamma$ components:

$$\begin{bmatrix} u_\alpha \\ u_\beta \\ u_\gamma \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} u_A \\ u_B \\ u_C \end{bmatrix}$$

For two phase AC/BI systems ($180°$) (with instantaneous values u_A and u_B) the following is being used:

$$\begin{aligned} u_\alpha &= \tfrac{1}{2}(u_A - u_B) \\ u_\beta &= 0 \\ u_\gamma &= \tfrac{1}{2}(u_A + u_B) \end{aligned}$$

For two phase AC systems ($120°$) (with instantaneous values u_A and u_B) the following is being used:

$$\begin{aligned} u_\alpha &= \tfrac{1}{\sqrt{3}}(u_A - u_B) \\ u_\beta &= 0 \\ u_\gamma &= \tfrac{1}{\sqrt{3}}(u_A + u_B) \end{aligned}$$

For single phase systems (with instantaneous values u_A) the following is being used:

$$\begin{aligned} u_\alpha &= u_A \\ u_\beta &= 0 \\ u_\gamma &= 0 \end{aligned}$$

Table 2.5: $\alpha\beta\gamma$ components and neutral voltage related variables for terminals

Name	**Unit**	**Description**
un	$p.u.$	Neutral-Ground Voltage
Un	kV	Neutral-Ground Voltage
$u0$	$p.u.$	Zero-Sequence Voltage
$U0$	kV	Zero-Sequence Voltage
$U0{\times}3$	kV	3*U0
$u1r$	$p.u.$	Voltage Phasor, Real Part
$u1i$	$p.u.$	Voltage Phasor, Imaginary Part
$phiu1$	deg	Voltage Phasor, Angle
$u1$	$p.u.$	Voltage Phasor, Magnitude
$u1pc$	$\%$	Voltage Phasor, Magnitude
$U1$	kV	Line-Ground Voltage Phasor, Magnitude
$U1l$	kV	Line to Line Voltage Phasor, Magnitude

The variables from Table 2.5 are calculated as follows:

- un is the neutral voltage available from the EMT simulation:

$$un = u_n$$

- Un is obtained as:
  for AC terminals ($120°$):
  $$Un = \sqrt{2} \cdot un \cdot uknom/\sqrt{3}$$
  for AC/BI terminals ($180°$):
  $$Un = \sqrt{2} \cdot un \cdot uknom/2$$
  where $uknom$ is the nominal voltage of the terminal.
- $u0$ is obtained as:
  $$u0 = u_\gamma$$
- $U0$ is obtained as:
  for AC terminals ($120°$):
  $$U0 = \sqrt{2} \cdot u0 \cdot uknom/\sqrt{3}$$
  for AC/BI terminals ($180°$):
  $$U0 = \sqrt{2} \cdot u0 \cdot uknom/2$$
  where $uknom$ is the nominal voltage of the terminal.
- $U0{\times}3$ is calculated as $3 \cdot U0$ for three phase, as $2 \cdot U0$ for two phase and as $U0$ for single phase systems.
- $u1r$ is the alpha component of the voltage:
  $$u1r = u_\alpha$$
- $u1i$ is the beta component of the voltage:
  $$u1i = u_\beta$$
- $phiu1$ is obtained as:
  $$phiu1 = \arctan\left(\frac{u_\beta}{u_\alpha}\right) \cdot \frac{180}{\pi}$$
- $u1$ is obtained as the magnitude of $u_\alpha + \jmath \cdot u_\beta$:
  $$u1 = \sqrt{u_\alpha^2 + u_\beta^2}$$
- $u1pc$ is obtained as:
  $$u1pc = u1 \cdot 100$$
- $U1$ is obtained as:
  for AC terminals ($120°$):
  $$U1 = u1 \cdot uknom/\sqrt{3}$$
  for AC/BI terminals ($180°$):
  $$U1 = u1 \cdot uknom/2$$
  where $uknom$ is the nominal voltage of the terminal. Please note that this variable is represented by an effective value (is not multiplied with $\sqrt{2}$).

- $U1l$ is obtained as:
for 2-phase and 3-phase terminals:

$$U1l = u1 \cdot uknom$$

for 1-phase terminals:

$$U1l = U1$$

Please note that this variable is represented by an effective value.

2.1.6 Neutral short circuit current related variables for terminals

If a short circuit event is defined at the terminal, the short circuit current flowing through the neutral can be monitored by these variables.

Table 2.6: Neutral short circuit current related variables for terminals

Name	Unit	Description
$Inshc$	kA	Neutral Short-Circuit Current, Magnitude
$inshc$	$p.u.$	Neutral Short-Circuit Current, Magnitude

The variables from Table 2.6 are calculated as follows:

- $Inshc$ is the magnitudes of the short circuit currents at the terminal flowing through the short circuit impedance:

$$Inshc = I_N$$

- $inshc$ is obtained as:

$$ishc = \frac{Inshc}{\sqrt{2} \cdot I_{nom\_1MVA}}$$

where $I_{nom\_1MVA} = \dfrac{1}{\sqrt{3} \cdot uknom}$ is the nominal current for $1MVA$ and $uknom$ is the nominal voltage of the connected terminal.

2.1.7 Frequency related variables for terminals

The frequency calculation is based on the positive sequence voltage which is transformed from the phase values through the symmetrical components.

Table 2.7: Frequency related variables for terminals

Name	Unit	Description
$frnom$	Hz	Nominal Frequency
fe	$p.u.$	Electrical Frequency
$fehz$	Hz	Electrical Frequency
$dfehz$	Hz	Deviation of the Electrical Frequency
$frdev$	Hz	Average frequency

The result variables from Table 2.7 are calculated as follows:

- $frnom$ is the nominal frequency defined in the Grid (*ElmNet*).
- fe is calculated by measuring the phase variation between the past and present voltage ($\underline{u} = u_\alpha + \jmath \cdot u_\beta$) with respect to the integration step size.
- $dfedt$ is calculated using the past and present frequency values and the integration step size.
- $fehz$ is calculated as:

$$fehz = fe \cdot frnom$$

- $dfehz$ is calculated as:

$$dfehz = fehz - frnom$$

- $frdev$ is the average frequency value calculated using all terminals.

2.2 Result variables for elements

The result variables available for single- and multiple-port elements after an EMT simulation are presented in the following sub chapters.

2.2.1 Voltage related variables for elements

The voltage related variables for the terminals are all based on the instantaneous voltages u_A, u_B, u_C and u_N resulting from the EMT simulation.

For the element based variables, the relationship between the absolute and per unit value voltage is $U_A = u_A \cdot U_{base}$ where the base voltage is $U_{base} = \sqrt{2} \cdot U_{nom\_el}/\sqrt{3}$ where U_{nom_el} is the nominal line to line voltage of the element. Due to the change in base, the per unit values are multiplied with the factor $uknom/U_{nom\_el}$.

Table 2.8: Voltage related variables for elements

Name	Unit	Description
$u{:}A$	$p.u.$	Phase Voltage
$u{:}B$	$p.u.$	Phase Voltage
$u{:}C$	$p.u.$	Phase Voltage
$u{:}N$	$p.u.$	Phase Voltage

The result variables from Table 2.8 are calculated as follows:

- $u{:}A$, $u{:}B$, $u{:}C$, $u{:}N$ are obtained as:

$$u{:}A = u_A \cdot \frac{uknom}{U_{nom\_el}}$$
$$u{:}B = u_B \cdot \frac{uknom}{U_{nom\_el}}$$
$$u{:}C = u_C \cdot \frac{uknom}{U_{nom\_el}}$$
$$u{:}N = u_N \cdot \frac{uknom}{U_{nom\_el}}$$

2.2.2 Current related variables for elements

The current related variables for the elements are all based on the instantaneous currents from the EMT simulation. The relationship between the absolute and per unit value current is $I_A = \sqrt{2} \cdot i_A \cdot I_{nom\_el}$ where $I_{nom\_el} = \dfrac{MVA_{el}}{\sqrt{3} \cdot U_{nom\_el}}$ is the nominal current of the element.

Table 2.9: Current related variables for elements

Name	Unit	Description
$I{:}A$	kA	Phase Current
$I{:}B$	kA	Phase Current
$I{:}C$	kA	Phase Current
$I{:}N$	kA	Phase Current
$i{:}A$	$p.u.$	Phase Current
$i{:}B$	$p.u.$	Phase Current
$i{:}C$	$p.u.$	Phase Current
$i{:}N$	$p.u.$	Phase Current

The result variables from Table 2.9 are calculated as follows:

- $I{:}A$, $I{:}B$, $I{:}C$, $I{:}N$ are the instantaneous currents available from the EMT Simulation:

$$I{:}A = I_A$$
$$I{:}B = I_B$$
$$I{:}C = I_C$$
$$I{:}N = I_N$$

- $i{:}A$, $i{:}B$, $i{:}C$, $i{:}N$ are obtained as:

$$i{:}A = \frac{I{:}A}{\sqrt{2} \cdot I_{nom\_el}}$$
$$i{:}B = \frac{I{:}B}{\sqrt{2} \cdot I_{nom\_el}}$$
$$i{:}C = \frac{I{:}C}{\sqrt{2} \cdot I_{nom\_el}}$$
$$i{:}N = \frac{I{:}N}{\sqrt{2} \cdot I_{nom\_el}}$$

2.2.3 Miscellaneous variables per phase for elements

Table 2.10: Miscellaneous variables per phase for elements

Name	Unit	Description
$TfctPh{:}A$	s	Fault Clearing Time
$TfctPh{:}B$	s	Fault Clearing Time
$TfctPh{:}C$	s	Fault Clearing Time
$TfctPh{:}N$	s	Fault Clearing Time

The result variables from Table 2.10 are calculated as follows:

- $TfctPh{:}A$, $TfctPh{:}B$, $TfctPh{:}C$, $TfctPh{:}N$ give the fault clearing time of a fuse or a relay located in the local cubicle. If the fuse/relay model is not triggered with the current, a default value of $9999{,}999s$ is used.

2.2.4 Voltage $\alpha\beta\gamma$ components related variables for elements

In addition to the phase voltage quantities, also $\alpha\beta\gamma$ components are available.

To project the phase quantities to a stationary reference frame the $\alpha\beta\gamma$ transformation is being used. This transformation (also called the Clarke transformation) is used for transferring the three phase instantaneous values available from the EMT simulation to $\alpha\beta\gamma$ components. The same is valid as in 2.1.5.

Table 2.11: Voltage $\alpha\beta\gamma$ components related variables for elements

Name	Unit	Description
$u0$	$p.u$	Zero-Sequence-Voltage
$u1r$	$p.u$	Voltage Phasor, Real Part
$u1i$	$p.u$	Voltage Phasor, Imaginary Part
$phiu1$	deg	Voltage Phasor, Angle
$u1$	$p.u$	Voltage Phasor, Magnitude
$U1$	kV	Line-Ground Voltage Phasor, Magnitude
$U1l$	kV	Line-Line Voltage Phasor, Magnitude

The variables from Table 2.11 are calculated as follows:

- $u0$ is obtained as:

$$u0 = u_\gamma \cdot \frac{uknom}{U_{nom\_el}}$$

where $uknom$ is the nominal voltage of the connected terminal and U_{nom_el} is the nominal voltage of the element.

- $u1r$ is the alpha component of the voltage:

$$u1r = u_\alpha \cdot \frac{uknom}{U_{nom\_el}}$$

- $u1i$ is the beta component of the voltage:

$$u1i = u_\beta \cdot \frac{uknom}{U_{nom\_el}}$$

- $phiu1$ is obtained as:

$$phiu1 = \arctan\left(\frac{u_\beta}{u_\alpha}\right) \cdot \frac{180}{\pi}$$

- $u1$ is obtained as:

$$u1 = \sqrt{u_\alpha^2 + u_\beta^2} \cdot \frac{uknom}{U_{nom\_el}}$$

- $U1$ is obtained as:
  for AC elements ($120°$):

$$U1 = \sqrt{2} \cdot u1 \cdot U_{nom\_el} / \sqrt{3}$$

  for AC/BI elements ($180°$):

$$U1 = \sqrt{2} \cdot u1 \cdot U_{nom\_el} / 2$$

  Please note that this variable represents the effective value (is not multiplied with $\sqrt{2}$).

- $U1l$ is obtained as:
  for 2-phase and 3-phase elements:

$$U1l = u1 \cdot U_{nom\_el}$$

  for 1-phase elements:

$$U1l = U1$$

  Please note that this variable represents the effective value (is not multiplied with $\sqrt{2}$).

2.2.5 Current $\alpha\beta\gamma$ components related variables for elements

In addition to the phase voltage quantities, also $\alpha\beta\gamma$ components are available.

To project the phase quantities to a stationary reference frame the $\alpha\beta\gamma$ transformation is being used. This transformation (also called the Clarke transformation) is used for transferring the three phase instantaneous values available from the EMT simulation to $\alpha\beta\gamma$ components I_α, I_β and I_γ. The same is valid as in 2.1.5.

Table 2.12: Current $\alpha\beta\gamma$ components related variables for elements

Name	Unit	Description
$I0$	kA	Zero-Sequence Current
$I0{\times}3$	kA	3*I0
$i0$	$p.u$	Zero-Sequence Current
$i1$	$p.u$	Current Phasor, Magnitude
$i1r$	$p.u$	Current Phasor, Real Part
$i1i$	$p.u$	Current Phasor, Imaginary Part
$phii1$	deg	Current Phasor, Angle
$I1$	kA	Current Phasor, Magnitude
$i1P$	$p.u.$	Current Phasor, Active Current
$i1Q$	$p.u.$	Current Phasor, Reactive Current
$I1P$	kA	Current Phasor, Active Current
$I1Q$	kA	Current Phasor, Reactive Current
$phiu1i1$	deg	Angle between Voltage and Current Phasor

The result variables from Table 2.12 are calculated as follows:

- $I0$ is obtained as:

$$I0 = I_\gamma$$

- $I0{\times}3$ is obtained as $3 \cdot I0$ for three phase, as $2 \cdot I0$ for two phase and as $I0$ for single phase systems.
- $i0$ is obtained as:

$$i0 = \frac{I_\gamma}{\sqrt{2} \cdot I_{nom\_el}}$$

  where I_{nom_el} is the nominal current of the element.
- $i1$ is obtained as:

$$i1 = \frac{\sqrt{I_\alpha^2 + I_\beta^2}}{\sqrt{2} \cdot I_{nom\_el}}$$

  where I_{nom_el} is the nominal current of the element.
- $i1r$ is the alpha component and is obtained as:

$$i1r = \frac{I_\alpha}{\sqrt{2} \cdot I_{nom\_el}}$$

  where I_{nom_el} is the nominal current of the element.
- $i1i$ is the beta component and is obtained as:

$$i1i = \frac{I_\beta}{\sqrt{2} \cdot I_{nom\_el}}$$

  where I_{nom_el} is the nominal current of the element.
- $phii1$ is obtained as:

$$phii1 = \arctan\left(\frac{I_\beta}{I_\alpha}\right) \cdot \frac{180}{\pi}$$

- $I1$ is obtained as the magnitude of the positive sequence current:

$$I1 = \frac{\sqrt{I_\alpha^2 + I_\beta^2}}{\sqrt{2}}$$

  Please note that this variable represents the effective value (it is divided with $\sqrt{2}$).
- $I1P$ is obtained as:

$$I1P = I1 \cdot \cos(\phi_1)$$

  where ϕ_1 is the angle between the active and reactive power sum variables $Psum$ and $Qsum$ as defined in Section 2.2.6.
- $I1Q$ is obtained as:

$$I1Q = I1 \cdot \sin(\phi_1)$$

- $i1P$ is obtained as:

$$i1P = i1 \cdot \cos(\phi_1) = \frac{I1P}{I_{nom\_el}}$$

- $i1Q$ is obtained as:

$$i1Q = i1 \cdot \sin(\phi_1) = \frac{I1Q}{I_{nom\_el}}$$

- $phiu1i1$ is obtained as:

$$phiu1i1 = phiu1 - phii1$$

2.2.6 Power $\alpha\beta\gamma$ components related variables for elements

The complex apparent power is calculated for 3-phase elements using the voltage and current alpha and beta components:

$$\underline{S}_{sum} = 3 \cdot (U_\alpha + \jmath \cdot U_\beta) \cdot (I_\alpha + \jmath \cdot I_\beta)^*$$

Table 2.13: Power $\alpha\beta\gamma$ components related variables for elements

Name	Unit	Description
$Psum$	MW	Power-Phasor, Active Power
$Qsum$	$Mvar$	Power-Phasor, Reactive Power
$Ssum$	MVA	Power-Phasor, Apparent Power
$cosphi1$		Power-Phasor, Power Factor

The result variables from Table 2.13 are calculated as follows:

- $Psum$ and $Qsum$ is obtained as:
  for 3-phase elements:

  $$Psum = \underline{S}_{sum}.r$$
  $$Qsum = \underline{S}_{sum}.i$$

  for 2-phase AC/BI elements ($180°$):

  $$P_{sum} = 4 \cdot U_\alpha \cdot I_\alpha$$
  $$Q_{sum} = 0$$

  for 2-phase AC elements ($120°$):

  $$P_{sum} = 3 \cdot U_\alpha \cdot I_\alpha$$
  $$Q_{sum} = 0$$

  for 1-phase elements:

  $$P_{sum} = 2 \cdot U_\alpha \cdot I_\alpha$$
  $$Q_{sum} = 0$$

- $Ssum$ is obtained as:

  $$Ssum = \sqrt{Psum^2 + Qsum^2}$$

- $cosphi1$ is obtained as:

  $$cosphi1 = \cos(\phi_s)$$

  where the angle is defined for 3-phase elements as:

  $$\phi_s = \arctan\left(\frac{\underline{S}_{sum}.i}{\underline{S}_{sum}.r}\right)$$

  for 1-phase and 2-phase elements is the angle $\phi_s = 0°$.

2.2.7 Miscellaneous variables (min/max values) for elements

Table 2.14: Miscellaneous variables (min/max values) for elements

Name	Unit	Description
$Tfct$	s	Fault Clearing Time

The result variables from Table 2.14 are calculated as follows:

- $Tfct$ is the minimum from the fault clearing times: $TfctPh{:}A$, $TfctPh{:}B$, $TfctPh{:}C$, $TfctPh{:}N$.