POWERFACTORY

PowerFactory 2021

Technical Reference

Current Transformer

StaCt,TypCt

PF2021

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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1 General Description

The *CT* block simulates the behaviour of a current transformer. Internally two models are available: a "basic" model and a "detailed" model.

The "basic" model simulates only the current conversion operated by the CT ratio and by the CT windings connection.

The "detailed" model simulates the core saturation effect accordingly with the parameters defined by the IEC and the ANSI standards. Two different types of CT block are available: the three phase CT and the single phase CT. Each type has different input and output signals.

2 Integration in the relay scheme

The CT type class name is TypCt and the CT class name is StaCt. The CT block represents in the relay model scheme the current signals entry point. Usually the CT block is connected to the measurement block. In figure 2.1 the typical connection scheme of a three phase CT block is shown, in figure 2.2 the same scheme for a single phase CT . The CT is connected to the Measurement block inputs.

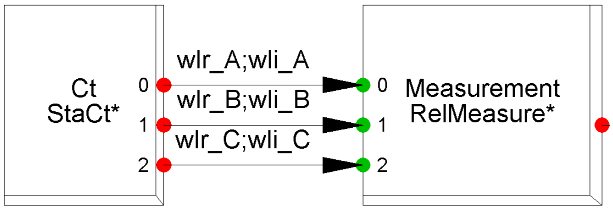

Figure 2.1: *Current Transformer* three phase connection scheme with measurement element

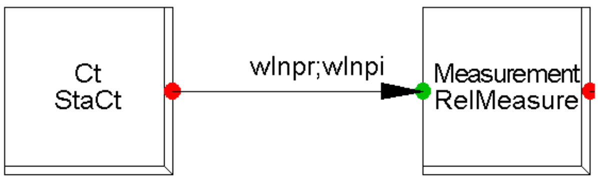

Figure 2.2: *Current Transformer* single phase connection scheme with measurement element

3 Features and User interface

3.1 Current Transformer Type (TypCt)

3.1.1 Basic data

The “Basic Data” tab page allows to define the available transformer ratios in terms of number of windings at the primary and the secondary side.

3.1.2 Additional data

In the “Additional data” tab page the CT accuracy can be defined using the IEC-Apparent Power and the ANSI Burden and Voltage standard.

When the selected standard is “Ansi ©-Burden”, the CT burden (“Zb” variable) is entered directly. When the selected standard is not “Ansi ©-Burden”, the CT burden (“Zb” variable) is calculated using the following formulas:

Ansi ©Voltage:

$$Z_b = \frac{V_{max}}{aclimit \cdot I_n} \tag{1}$$

IEC Apparent Power:

$$Z_b = \frac{S_{nom}}{I_n \cdot I_n} \tag{2}$$

where:
V_{max} = Voltage Limit (“Vm” variable)
$aclimit$ = Accuracy Limit Factor (“aclimit” variable in the Current Transformer Type dialogue (“TypCt” class))
I_n = Secondary side CT rated current
S_{nom}= Apparent Power(“Snom” variable)

3.2 Current Transformer (StaCt)

The user can change the block settings using the “Current Transformer”dialogue (“StaCt” class). The dialogue consists of three tab pages: *Basic data*, *Tripping times*, *Additional Data*, and *Description*. The main settings are located in the *Basic data* tab page.

3.2.1 Basic data

The “Basic Data” tab page of the CT dialogue (“StaCt” class) should be used to set the CT type (*Type* control), transformer ratio (*Primary* and *Secondary Tap* comboboxes), measurement point (*Location* control), orientation (*Orientation* combobox), secondary side connection (*Connection* combobox), number of phases (*No.Phases* combobox, “iphase” variable) and phase order (*Phase 1* and *Phase 2* comboboxes).

The block can be disabled using the *Out of service* check box.
The blue text provides additional info regarding the current ratio.

Please note that the *Location* control can point to another Current Transformer. In this way the other CT output signals can be used as input signals of the CT block. The *Location* control can point also to a cubicle("StaCubic" class), to a switch("StaSwitch" class) or to a 3 Windings transformer ("ElmTr3" class). When the *Location* control is not used the *Measure at* is displayed just below the *Branch* control and it allows setting the measurement point at the switch position or at CT block itself.

3.2.2 Additional Data

The internal model is by default the *basic* model. To take into account of the saturation effects the detailed model can be activated using the *Detailed Model* check box in the "Additional data" tab page of the CT block dialogue ("StaCt" class).

4 Transfer functions

When the “Detailed model” is not enabled the following transfer formulas are applied:

- When the primary connection is *Y* and the secondary connection is *Y*:

$$I_{xsecondary} = I_{xprimary}/ratio \tag{3}$$

where:
$ratio =$ the CT transformer ratio
$x =$ phase a,b,c

- When the primary connection is *Y* and the secondary connection is *D*:

$$I_{xsecondary} = (I_{xprimary} - I_{yprimary})/ratio \tag{4}$$

where:
$ratio =$ the CT transformer ratio
$x =$ phase b,c,a
$y =$ phase a,b,c

- When the CT is located in a bus bar cubicle or when the *Location* control is pointing to a cubicle or to a switch the rated voltage of the bus bar at which the cubicle (or the switch) belongs is used to calculate the following formula:

$$I_{xprimary} = 1000/(\sqrt{3} \cdot U_n) \tag{5}$$

- When the *Location* control is pointing to another CT or to a 3 windings transformer the following formula is used:

$$I_{xprimary} = I \cdot unit \tag{6}$$

where:
$unit =$ 1 for the *other CT* case and $unit =$ 1000 for the three windings transformer case (to take care of the transformer rated power unit).

4.1 Load Flow, Short-circuit and RMS simulation Model

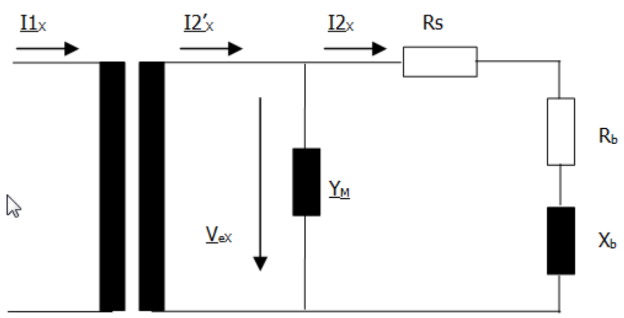

Figure 4.1: *Current Transformer* Load Flow, Short Circuit, RMS model.

The saturation of the magnetizing admittance is not considered for this model. The magnetizing admittance is calculated as:

$$Y_M = -j \cdot curmg/Z_{bnom} \tag{7}$$

where:
$curmg$ is the Excitation Current /Rated Current (in the CT element, “StaCt” class).
$Zbnom$ is the nominal burden impedance.

The burden impedance Z_b is calculated by using the CT element parameter *Zburd* and *cosburd* with the following formula:

$$Z_b = R_b + jX_b = Z_{burd} \cdot cos(cosburd) + jZ_{burd} \cdot \sqrt{1 - cosburd^2} \tag{8}$$

4.1.1 CT with Y connection on secondary side

The secondary current is calculated with the following formula:

$$\begin{aligned} I2_x &= I2'_x \cdot \frac{1}{1 + Y_M \cdot (R_s + Z_b)} \\ I2'_x &= \frac{I1_x}{ratio} \end{aligned} \tag{9}$$

where:
$I1_x =$ primary current with x = phase A,B,C
$ratio =$CT transformer winding ratio = ptapset/stapset (primary tap / secondary tap).

4.1.2 CT with D connection on the secondary side

The secondary current is calculated using the following equations:

$$I2_x = I_{bx} - I_{by} \tag{10}$$

where:
x is phase A,B,C and *y* is phase B,C,A and

$$\begin{aligned} I_{bx} &= (I2'_x - I2_0) \cdot \frac{1}{1 + Y_M \cdot (R_s + 3 \cdot Z_b)} \\ I2_0 &= (I2'_A + I2'_B + I2'_C)/3 \\ I2'_x &= \frac{I1_x}{ratio} \end{aligned} \tag{11}$$

where:
x is phase A,B,C and *y* is phase B,C,A
$ratio =$CT transformer winding ratio = ptapset/stapset (primary tap / secondary tap).

The excitation voltage is calculated:

$$\begin{aligned} V_{ex} &= I_{bx} \cdot (R_s + 3 \cdot Z_b) \cdot R_s \cdot I_{D0} \\ I_{D0} &= I2_0 \cdot \frac{1}{1 + Y_M \cdot R_s} \end{aligned} \tag{12}$$

where *x* is phase A,B,C.

4.2 EMT simulation Model

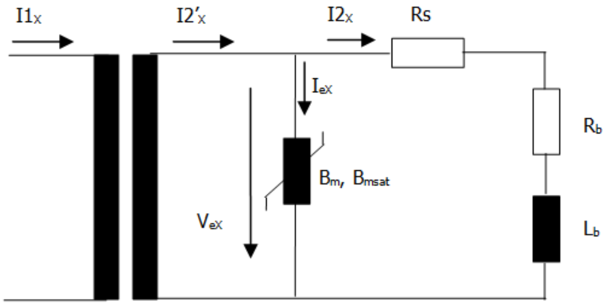

Figure 4.2: *DIgSILENT* The *Current Transformer* “StaCt” EMT simulation model.

The Magnetizing Inductance $(1/Lm)$ is calculated accordingly with the following formula:

$$B_m = \frac{curmg}{Z_{bnom}} \cdot \omega_N \tag{13}$$

where:
$curmg$ is the Excitation Current /Rated Current (in the CT element, “StaCt” class).
$Zbnom$ is the nominal burden impedance.
$\omega_N = 2\pi F_{nom}$ with F_{nom} = Nominal Frequency.

The Saturated Magnetizing inductance $(1/Lmsat)$ is calculated accordingly with the following formula:

$$B_{msat} = \frac{b_{msat}}{Z_{bnom}} \cdot \omega_N \tag{14}$$

where:
$bmsat$ is the Saturated Admittance in p.u. (based on the nominal burden impedance).
$\omega_N = 2\pi F_{nom}$ with F_{nom} = Nominal Frequency.
$Zbnom$ is the nominal burden impedance calculated as follow:

$$L_b = Z_{burd} \cdot \frac{\sqrt{1 - cosburd^2}}{\omega_N} \tag{15}$$

The derivative of the magnetic flux is calculated with the following formula:

$$\frac{d\Psi m_x}{dt} = \omega_N \cdot V_{ex} \tag{16}$$

where:
x is phase A,B,C.
V_{ex} is the excitation voltage for the phase x.
$\omega_N = 2\pi F_{nom}$ with F_{nom} = Nominal Frequency.

4.2.1 CT with Y connection on secondary side

The excitation voltage is calculated with the following formula:

$$
\begin{aligned}
V_{ex} &= (R_s + R_b) \cdot I2'_x + L_b \cdot \frac{dI2'_x}{dt} \\
I2'_x &= \sqrt{2} \cdot \frac{I1_x}{ratio} - I_{ex}
\end{aligned}
\tag{17}
$$

where:
$I1_x$ is the primary current with x = phase A,B,C
$ratio =$CT transformer winding ratio = “ptapset”/“stapset” (primary tap / secondary tap).
I_{ex} is the Excitation Current with x = phase A,B,C.

4.2.2 CT with D connection on secondary side

The excitation voltage is calculated with the following formula:

$$
\begin{aligned}
V_{ex} &= R_s \cdot (I2'_x + I_{D0}) + 3 \cdot R_b \cdot I2'_x + 3 \cdot L_b \cdot \frac{dI2'_x}{dt} \\
I_{D0} &= 1/3 \cdot \left(\sqrt{2} \cdot \frac{I1_A + I1_B + I1_C}{ratio} - I_{eA} - I_{eB} - I_{eC} \right)
\end{aligned}
\tag{18}
$$

where:
I_{ex} = Excitation Current with x = phase A,B,C $I1_A$ is the phase A primary current.
$I1_B$ is the phase B primary current.
$I1_C$ is the phase C primary current.
$ratio =$CT transformer winding ratio = “ptapset”/“stapset” (primary tap / secondary tap).
I_{eA} = Phase A Excitation Current.
I_{eB} = Phase B Excitation Current.
I_{eC} = Phase C Excitation Current.

The secondary current is:

$$
I2'_x = \sqrt{2} \cdot \frac{I1_x}{ratio} - I_{ex} - I_{D0}
\tag{19}
$$

where:
$I1_x$ is the primary current with x = phase A,B,C.
$ratio =$CT transformer winding ratio = “ptapset”/“stapset” (primary tap / secondary tap).
I_{ex} = Excitation Current with x = phase A,B,C.

5 Saturation models

5.1 Piecewise Linear

In the non-saturated condition $\Psi m_x < \Psi m_{knee}$ the excitation current is calculated by the following equation:

$$I_{ex} = \frac{B_m}{\omega_N} \cdot \Psi m_x \tag{20}$$

In the saturated condition where $\Psi m_x > \Psi m_{knee}$ by the following equation:

$$I_{ex} = I_{knee} + \frac{B_{msat}}{\omega_N} \cdot (\Psi m_x - \Psi m_{knee}) \tag{21}$$

with:

$$\begin{aligned} I_{knee} &= \frac{B_m}{\omega_N} \cdot \Psi m_{knee} \\ \Psi m_{knee} &= \sqrt{2} \cdot V_s \end{aligned} \tag{22}$$

where
$V_s =$ is the *Saturation Voltage* (“Vs” variable in the “Excitation Parameter” frame in the Current Transformer dialogue (“StaCt” class)).

5.2 Polynomial

When not saturated $\Psi m_x < \Psi m_{knee}$:

$$I_{ex} = \frac{B_m}{\omega_N} \cdot \Psi m_x \cdot \left(1 + \left| \left(\frac{\Psi m_x}{\Psi m_0}\right)^{ksat} \right| \right) \tag{23}$$

When saturated $\Psi m_x > \Psi m_{knee}$:

$$I_{ex} = I_{knee} + \frac{B_{msat}}{\omega_N} \cdot (\Psi m_x - \Psi m_{knee}) \tag{24}$$

with:

$$\begin{aligned} I_{knee} &= \frac{B_m}{\omega_N} \cdot \Psi m_{knee} \cdot \left(1 + \left(\frac{\Psi m_{knee}}{\Psi m_0}\right)^{ksat}\right) \\ \Psi m_0 &= \Psi m_{knee} \cdot e^{-\frac{\ln\left(\frac{\frac{B_{msat}}{B_m} - 1}{ksat + 1}\right)}{ksat}} \\ \Psi m_{knee} &= \sqrt{2} \cdot \left(\frac{K_{sat} + 1}{ksat}\right) \cdot V_s \end{aligned} \tag{25}$$

where:
$ksat$ is the *Exponent* (“Ksat” variable in the “Excitation Parameter” frame in the Current Transformer dialogue (“StaCt” class)).

$V_s =$ is the *Saturation Voltage* (“Vs” variable in the “Excitation Parameter” frame in the Current Transformer dialogue (“StaCt” class)).

A Parameter Definitions

A.1 Current Transformer Type (TypCt)

Table A.1: Input parameters of Ct type (*TypCt*)

Parameter	Description	Unit
loc_name	Name assigned by the user to the block type	Text
Primtaps	The list of the available number of windings at the primary side (i.e. 50,100,200,500 etc)	Array of real numbers
Sectaps	List of the available number of windings at the secondary side (i.e. 1, 5)	Array of real numbers
iopt_sat	The kind of CT representation. It can be “IEC- Apparent Power” internal string:“iec”, “ANSI©-Burden” internal string:“anscb”or “ANSI©-Voltage” internal string:“anscv”	Text
Snom	Current transformer apparent power (“IEC-Apparent Power” representation)	VA
Zb	Burden impedance (“ANSI©-Burden” representation)	Ohm
Vmax	Voltage limit (default values 100, 200,400,500,800) (“ANSI©-Voltage” representation)	Volt
raclass	Accuracy class (default values: 5,10)	Integer
aclimit	Accuracy limit factor (default values: 5, 10, 15, 20, 30)	Integer
Ithr	Rated short circuit current (the max current which can be sustained or 1 sec)	Primary Amperes

A.2 Current Transformer (StaCt)

Table A.2: Input parameters of Ioc element (*RelIoc*))

Parameter	Description	Unit
loc_name	Name assigned to the user to the block element	Text
Typ_id	Pointer to the relevant TyIoc object	Pointer
Outserv	Flag to put out of service the block	Y/N
loc_name	The user assigned name of the Ct type	Text
typ_id	Pointer to the CT type object (TypCt clas)	Pointer
outserv	Flag to enable /disable the block	Integer
pbranch	Location where the CT is (if it is not set the default location is the cubicle where the CT has been created)	Pointer
ilocation	Place where the CT is measing the current (it can be “Circuit element” id = 0, “Element” id = 1	Integer
iorient	CT orientation (it can be “Branch” internal id = 0 or “Busbar” internal id = 1	Integer
ptapset	Primary side number of windings (its one of the value listed in the “primtaps” list in the TypCt object)	Real number
itapset	Secondary side number of windings (its one of the value listed in the “sectaps” list in the TypCt object)	Real number
stapcon	Secondary side connection type (it can be “Y” internal id = 0 or “D” internal id = 1)	Integer
iphase	CT number of phases (it can be “1”, “2” or “3”)	Integer
it2p1	Phase 1 name (it can be “a”, “b”,“c”,“N”,“I0”)	Integer
it2p2	Phase 2 name (it can be “a”, “b”,“c”)	Integer
Iconsat	Detailed model (considering saturation) activation flag	Integer
Zburd	Burden impedance	Real number Ohm
cosburd	Burden cosϕ	Real number
Rs	Secondary winding resistance	Real number Ohm
itrmt	Saturation model (it can be “Piecewise Linear” internal ID = 0 or “Polynomial” internal ID = 1)	Integer
curmg	Excitation Current/rated Current	Real number pu
bmsat	Saturated Admittance	Real number Ohm
Vs	Saturation Voltage	Real number Volt
ksat	Saturation exponent for the polynomial representation . Typical values are 9,13,15.	Integer

B Signal Definitions

B.1 Single phase

Table B.1: Input/output signals of the single phase StaCt element (*CalStaCt1p*)

Name	Description	Unit	Type	Model
Ir_A	Ct block phase A primary side current real part	Primary Amps	IN	Any
Ir_B	Ct block phase B primary side current real part	Primary Amps	IN	Any
Ir_C	Ct block phase C primary side current real part	Primary Amps	IN	Any
Ii_A	Ct block phase A primary side current imaginary part	Primary Amps	IN	Any
Ii_B	Ct block phase B primary side current imaginary part	Primary Amps	IN	Any
Ii_C	Ct block phase C primary side current imaginary part	Primary Amps	IN	Any
I2r	Secondary side current real part	Secondary Amps	OUT	Any
I2i	Secondary side current imaginary part	Secondary Amps	OUT	Any
I2r_A	Secondary side current real part (equal to I2r)	Secondary Amps	OUT	Any
I2i_A	Secondary side current imaginary part (equal to I2i)	Secondary Amps	OUT	Any
I0x3r	Zero sequence current real part (calculated internally)	Secondary Amps	OUT	Any
I0x3i	Zero sequence current imaginary part (calculated internally)	Secondary Amps	OUT	Any

B.2 3 phase

Table B.2: Input/output signals of 3 phase Current Transformer element (*CalStaCt*)

Name	Description	Unit	Type	Model
Ir_A	Ct block phase A primary side current real part pu	Primary Amperes	IN	Any
Ir_B	Ct block phase B primary side current real part pu	Primary Amperes	IN	Any
Ir_C	Ct block phase C primary side current real part pu	Primary Amperes	IN	Any
Ii_A	Ct block phase A primary side current imaginary part pu	Primary Amperes	IN	Any
Ii_B	Ct block phase B primary side current imaginary part pu	Primary Amperes	IN	Any
Ii_C	Ct block phase C primary side current imaginary part pu	Primary Amperes	IN	Any
I2r_A	Phase A secondary side current real part	Secondary Amperes	OUT	Any
I2r_B	Phase B secondary side current real part	Secondary Amperes	OUT	Any
I2r_C	Phase C secondary side current real part	Secondary Amperes	OUT	Any
I2i_A	Phase A secondary side current imaginary part	Secondary Amperes	OUT	Any
I2i_B	Phase B secondary side current imaginary part	Secondary Amperes	OUT	Any
I2i_C	Phase C secondary side current imaginary part	Secondary Amperes	OUT	Any
I0x3r	Zero sequence secondary side current real part (calculated internally)	Secondary Amperes	OUT	Any
I0x3i	Zero sequence secondary side current imaginary part (calculated internally)	Secondary Amperes	OUT	Any

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