POWERFACTORY

PowerFactory 2021

Technical Reference

Series RLC-Filter

ElmSfilt

POWER SYSTEM SOLUTIONS
MADE IN GERMANY

PF2021

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Contents

1 General Description

The series RLC-filter model is implemented as a single-tuned filter (series RLC circuit), as shown in Figure 1.1.

Figure 1.1: Series RLC-Filter element

The general parameters of the series RLC-filter are defined in Table 1.1

Table 1.1: General input parameters

Parameter	Default Value	Description	Range
loc_name		Name	
bus1		Terminal (StaCubic)	
bus1_bar		Terminal	
cpZone		Zone	
cpArea		Area	
outserv	0	Out of Service	$0 \leq x \leq 1$
ratings			
pRating		Thermal Rating	
systyp	AC	System Type	AC
nphases	3	No. of Phases	1:3

2 Load Flow Analysis

There are two different models:

- Model for balanced calculations
- Model for unbalanced calculations

2.1 Balanced AC Load Flow

In Balanced Load Flow, the following model is used:

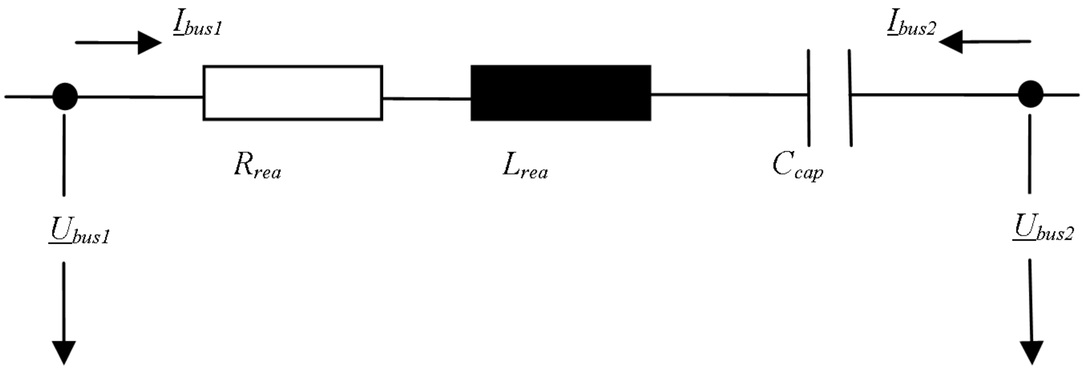

Figure 2.1: Balanced Load Flow Model

Where:

- R_{rea} is the resistance in Ω
- L_{rea} is the reactance in mH
- C_{cap} is the susceptance in μF

From these values, we can obtain the reactance and susceptance values:

- $X_{rea} = 2\pi f \cdot L_{rea} \cdot 1e^{-3}$ is the reactance in Ω
- $B_{cap} = 2\pi f \cdot C_{cap} \cdot 1e^{-6}$ is the susceptance in S
- f is the network frequency in Hz

The initialisation of the impedance is calculated as follows:

$$\underline{Z}_{rl} = R_{rea} + \jmath X_{rea} \tag{1}$$

$$X_{cap} = \frac{1}{B_{cap}} \tag{2}$$

$$\underline{Z} = \underline{Z}_{rl} - \jmath X_{cap} \tag{3}$$

The equations for voltage and current are:

$$\underline{U}_{bus1} - \underline{U}_{bus2} = \underline{I}_1 \cdot \underline{Z} \tag{4}$$

$$\underline{I}_{bus1} + \underline{I}_{bus2} = 0 \tag{5}$$

Where:

- $\underline{U}_{bus1}$ is the line to ground voltage in terminal 1 in kV
- $\underline{U}_{bus2}$ is the line to ground voltage in terminal 2 in kV

- $\underline{I}_{bus1}$ is the current in terminal 1 in kA
- $\underline{I}_{bus2}$ is the current in terminal 2 in kA

The voltage across the capacitor, u_c in p.u. is calculated as follows:

$$u_c = \left| \frac{\underline{U}_{bus1} - \underline{U}_{bus2} - \underline{I}_{bus1} \cdot \underline{Z}_{rl}}{\underline{U}_{bus1}} \right|$$

2.1.1 Zero Capacitance

If the value for C_{cap} is zero, the series filter is modelled as a R-L circuit, and in such a case, the initialization of the impedance is calculated as follows:

$$\underline{Z}_{rl} = R_{rea} + \jmath X_{rea}$$
$$\underline{Z} = \underline{Z}_{rl}$$

The equations for voltage and current are the same as 4 and 5.

2.1.2 Input Parameters

The input parameters for balanced Load Flow calculation are defined in Table 2.1.

Table 2.1: Input parameters for balanced load flow

Parameter	Unit	Default Value	Description	Symbol
rrea	mH		Resistance	R_{rea}
lrea	Ω		Inductance	L_{rea}
ccap	µF		Capacitance	C_{cap}

2.1.3 Calculation Parameters

The calculation parameters used in the RMS model are presented in Table 2.2.

Table 2.2: Calculation parameters for balanced load flow

Parameter	Unit	Description	Symbol
Zrl	Ω	Shunt Impedance	$\underline{Z}_{rl}$
Xcap	Ω	Capacitor Reactance	X_{cap}
frnom	Hz	Nominal Frequency	f
hpi	rad/s	Nominal Angular Frequency	$2\pi f$
uc	p.u.	Voltage across Capacitor	u_c

2.2 Unbalanced AC Load Flow

In Balanced Load Flow, the following model is used:

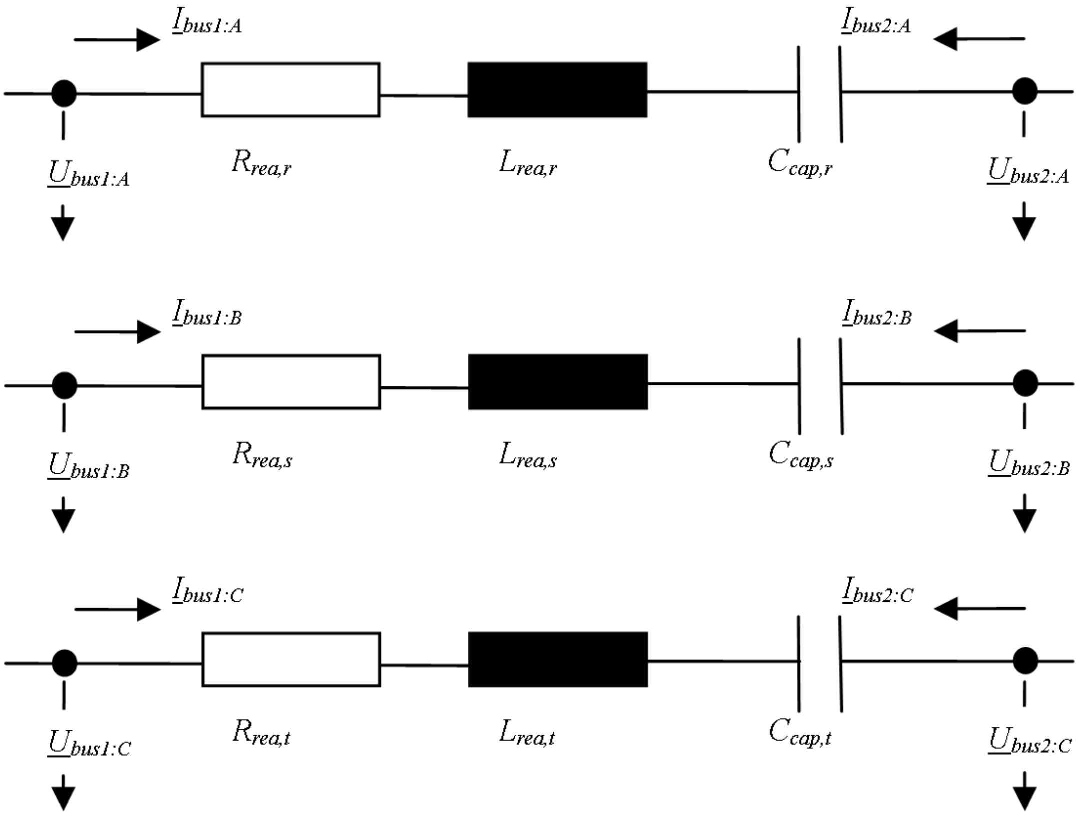

Figure 2.2: Unbalanced Load Flow Model

The parameters are as follows:

$$R_{rea:r} = R_{rea:s} = R_{rea:t} = R_{rea}$$
$$L_{rea:r} = L_{rea:s} = L_{rea:t} = L_{rea}$$
$$C_{cap:r} = C_{cap:s} = C_{cap:t} = C_{rea}$$

The equations for impedance, voltage and current for each phase are the same as those described in 1 to 5.

3 Short Circuit

The equations for short-circuit are the same used for load flow explained in Section 2.

4 RMS-Simulation

The equations for short-circuit are the same used for load flow explained in Section 2.

5 EMT-Simulation

In EMT Simulation, the following model is used:

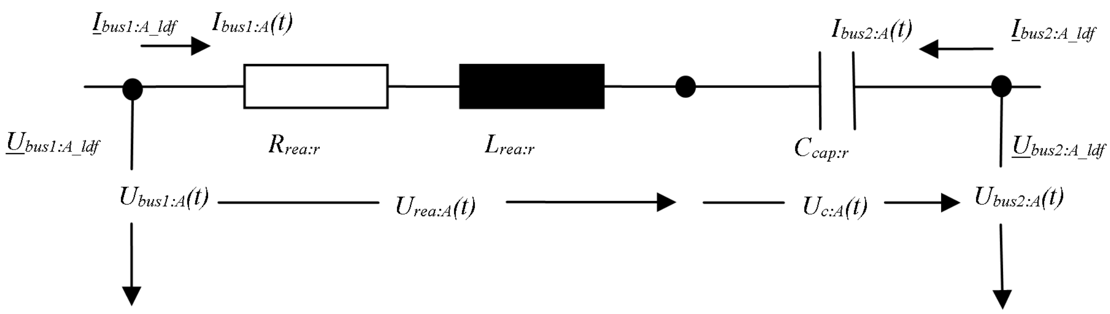

Figure 5.1: EMT Model

The parameters are as follows:

$$
\begin{aligned}
R_{rea:r} &= R_{rea:s} = R_{rea:t} = R_{rea} \\
L_{rea:r} &= L_{rea:s} = L_{rea:t} = L_{rea} \\
C_{cap:r} &= C_{cap:s} = C_{cap:t} = C_{rea}
\end{aligned}
$$

The initialisation of the equations for voltage and current are presented below:

$$
\begin{aligned}
U_{c:A}(0) &= \Re\left\{\underline{U}_{bus1:A\_ldf} - \underline{U}_{bus2:A\_ldf} - \underline{I}_{bus1:A\_ldf} \cdot (R_{rea:r} + \jmath 2\pi f \cdot L_{rea:r})\right\} \\
U_{c:B}(0) &= \Re\left\{\underline{U}_{bus1:B\_ldf} - \underline{U}_{bus2:B\_ldf} - \underline{I}_{bus1:B\_ldf} \cdot (R_{rea:s} + \jmath 2\pi f \cdot L_{rea:s})\right\} \\
U_{c:C}(0) &= \Re\left\{\underline{U}_{bus1:C\_ldf} - \underline{U}_{bus2:C\_ldf} - \underline{I}_{bus1:C\_ldf} \cdot (R_{rea:t} + \jmath 2\pi f \cdot L_{rea:t})\right\} \\
\frac{d(U_{c:A}(0))}{dt} &= \Re\{\jmath 2\pi f \cdot U_{c:A}(0)\} \\
\frac{d(U_{c:B}(0))}{dt} &= \Re\{\jmath 2\pi f \cdot U_{c:B}(0)\} \\
\frac{d(U_{c:C}(0))}{dt} &= \Re\{\jmath 2\pi f \cdot U_{c:C}(0)\}
\end{aligned}
$$

Finally, the equations for voltage and current in the series RLC-filter are:

$$U_{c:r}(t) = U_{bus1:A}(t) - U_{bus2:A}(t) - R_{rea:r} \cdot I_{bus1:A}(t) - L_{rea:r} \cdot \frac{d(I_{bus1:A}(t))}{dt}$$
$$U_{c:s}(t) = U_{bus1:B}(t) - U_{bus2:B}(t) - R_{rea:s} \cdot I_{bus1:B}(t) - L_{rea:s} \cdot \frac{d(I_{bus1:B}(t))}{dt}$$
$$U_{c:t}(t) = U_{bus1:C}(t) - U_{bus2:C}(t) - R_{rea:s} \cdot I_{bus1:B}(t) - L_{rea:s} \cdot \frac{d(I_{bus1:C}(t))}{dt}$$
$$I_{bus1:A}(t) = C_{cap:r} \cdot \frac{d(U_{c:r}(t))}{dt}$$
$$I_{bus1:B}(t) = C_{cap:s} \cdot \frac{d(U_{c:s}(t))}{dt}$$
$$I_{bus1:C}(t) = C_{cap:t} \cdot \frac{d(U_{c:t}(t))}{dt}$$
$$I_{bus1:A}(t) + I_{bus2:A}(t) = 0$$
$$I_{bus1:B}(t) + I_{bus2:B}(t) = 0$$
$$I_{bus1:C}(t) + I_{bus2:C}(t) = 0$$

5.1 Signals

The signals available in EMT simulation are presented in Table 5.1.

Table 5.1: *ElmSfilt* Signals (EMT-Simulation)

Parameter	Unit	IN/OUT	Description	Symbol
U_ca	kV	STATE	Voltage Across Capacitor, Phase A	$U_{c:A}$
U_cb	kV	STATE	Voltage Across Capacitor, Phase B	$U_{c:B}$
U_cc	kV	STATE	Voltage Across Capacitor, Phase C	$U_{c:C}$

6 Harmonics/Power Quality

The equations for voltage and current are the same as those described in Section 2, with the parameters calculated as described in the sections below.

In addition, frequency-dependent characteristics may be defined for the following parameters (parameter names follow in parentheses): R ($rrea$), L ($lrea$) and C ($ccap$).

Note: For absolute characteristics, the values defined in the element (not in the characteristic) will be used at the fundamental frequency.

6.1 Balanced Calculation

The parameters are as follows:

$$\underline{Z}_{rl} = R_{rea} + \jmath X_{rea} \cdot f_{harm} \tag{6}$$
$$X_{cap} = \frac{1}{B_{cap}} \cdot f_{harm} \tag{7}$$
$$\underline{Z} = \underline{Z}_{rl} - \jmath X_{cap} \tag{8}$$

Where f_{harm} is the harmonic order.

6.2 Unbalanced Calculation

The equations for impedance for each phase are the same as those described in 6 to 8.

List of Figures

List of Tables