POWERFACTORY

PowerFactory 2021

Technical Reference

Low-Voltage Load and Partial LV-Load

ElmLodlv,ElmLodlvp

PF2021

POWER SYSTEM SOLUTIONS

MADE IN GERMANY

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1 General Description

The focus of load flow calculations in low-voltage systems is usually to determine maximum branch currents as well as maximum voltage drop. In low-voltage systems the R/X ratio is considerably greater than 1. The voltage drop therefore depends mainly on the active power flow. Reactive power flow in low-voltage systems is of less interest.

The modelling of loads, as for distribution systems, represents a major challenge. In addition to the time dependency, a stochastic component is introduced in low-voltage systems which is usually expressed in the form of a coincidence factor. This takes into consideration that for two connections it is highly unlikely that both will draw maximum load at the same time. With three connections this is even more unlikely. Therefore, the maximum load current depends on the number of connections supplied by a cable.

PowerFactory provides a special low-voltage load model which is defined by the number of connections supplied. In addition, the load is assigned to a 'load category'. For each category, the maximum load of the connection and the coincidence factor are defined for an infinite number of connections (hence the relationship between average and maximum load).

Considering the stochastic independent component of low-voltage loads, the maximum load (dependent on the number of connections) can be described by:

$$S_{max}(n) = n \cdot g(n) \cdot S_{max}(1) \tag{1}$$

where

- n is the number of connections
- $g(n)$ is the maximum coincidence

If a Gaussian (normal) distribution is assumed for the coincidence, then the coincidence function is:

$$g(n) = g_{\infty} + \frac{1 - g_{\infty}}{\sqrt{n}} \tag{2}$$

This function depends solely on the coincidence of an infinite number of connections.

For the calculation of maximum branch utilization as well as maximum voltage drop, ***PowerFactory*** uses a probabilistic load flow calculation, which is able to calculate both maximum and average currents as well as average losses. This probabilistic load flow calculation can be applied to any system topology, including meshed low-voltage systems. Not only can the low-voltage loads be attached to network nodes, but also arbitrarily to line sections, thereby reducing clutter in the single line diagram.

2 Load Flow Analysis

Low-voltage loads and partial LV-loads (*ElmLodlv* and *ElmLodvp*, respectively) are modelled in ***PowerFactory*** with fixed and variable (stochastic) components. The parameters which define these fixed and variable components are set in both the load flow command dialog (i.e. globally), and in the load types' dialogs (i.e. locally).

The selection of the phase technology (3-phase, 2-phase, etc) is made via the *Basic Data* page of the low-voltage load element. The following phase technologies are supported:

- 3PH PH-E
- 3PH-'YN'
- 2PH-'YN'
- 1PH PH-PH
- 1PH PH-N
- 1PH PH-E

For load flow analysis, the data for the fixed portion of the load can be input according to one of four modes. These modes are available for selection on the *Basic Data* page of the low-voltage load (or partial LV-load) element dialog in the *Load Type* frame, and are the following:

- S,cos(phi): Enter apparent power and power factor
- P,cos(phi): Enter active power and power factor
- U,I,cos(phi): Enter voltage, current and power factor
- E,cos(phi): Enter yearly energy consumption, power factor, and consumption profile

For three-phase loads, the fixed load component can also be defined as unbalanced, by specifying the load data for each phase.

2.1 Partial Loads

The partial LV-load differs from the low-voltage load in that it is used to model line loads. This kind of load can only be defined inside ***PowerFactory*** line elements (*ElmLne*) by clicking on the *Line Loads* button on the *Load Flow* page, or within low-voltage load elements (*ElmLodlv*) by clicking on the *Add. Loads* button on the *Basic Data* page. The partial LV-load has no calculation results of its own and cannot be selected from the drawing toolbar, but is instead automatically displayed on the single line graphic (as illustrated in Figure 2.1) after it has been created.

A line load with total apparent power S_{tot} defined at a position $lnepos$ (in %) over a line is considered in *PowerFactory* by splitting the load in two parts. The first part is connected at the beginning of the line with apparent power $S_{tot} \cdot (100 - lnepos)$. The second part is connected at the end of the line with apparent power $S_{tot} \cdot lnepos$.

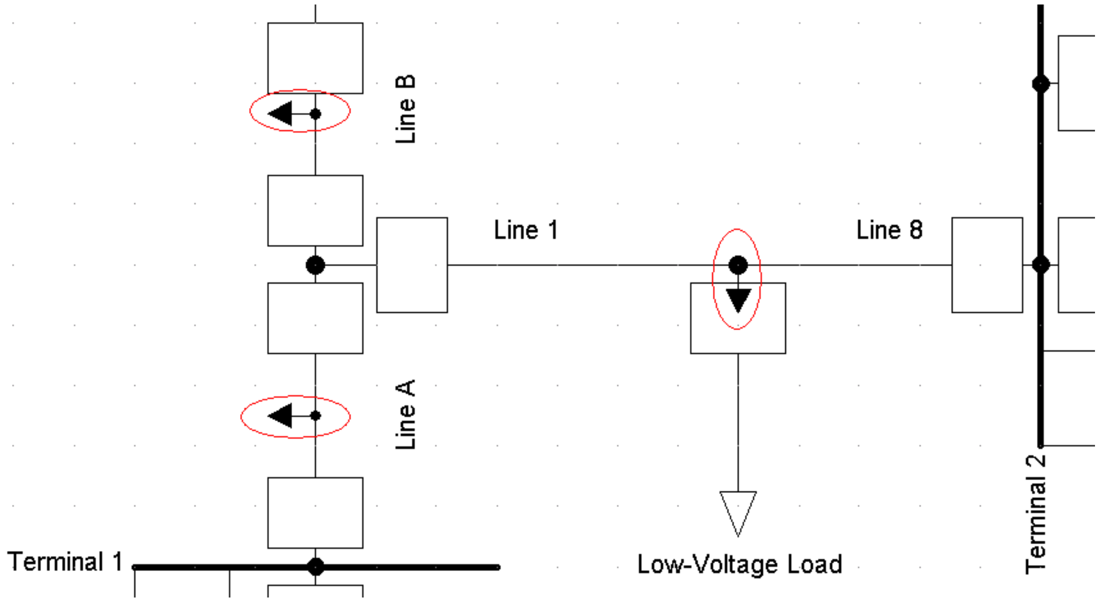

Figure 2.1: Partial LV-loads in single line diagram (indicated in red)

The following phase technologies are supported:

- 3PH PH-E
- 1PH PH-PH
- 1PH PH-N
- 1PH PH-E

Unbalanced load definition on a per-phase basis is supported for three-phase loads.

The *Fixed Load* frame is used to define the non-stochastic component of the load that is not subject to coincidence factors. Conversely, the *Variable Load* frame is used to define the stochastic component of the load that is subject to coincidence factors.

The low-voltage load element and the partial LV-load element may optionally have a low-voltage load type assigned. The following inputs are defined on *Basic Data* page: *Maximum Load per Customer* (in kVA), *Power Factor* of the load, and *Coincidence Factor (ginf)*, g_∞, as used in (1).

There are two different representations of the low-voltage load used by the load flow calculation:

- model for balanced load-flow analysis
- model for unbalanced load-flow analysis

These are described in Sections 2.3 and 2.4.

2.2 Voltage dependency

On the *Load Flow* page in the low-voltage load type, it is possible to specify the voltage dependency of low-voltage and partial low-voltage loads.

Note: This dependency is only taken into account if the flag *Consider Voltage Dependency of Loads* in the *Load Flow Calculation* command dialog is selected.

Voltage dependency of low-voltage loads can be specified as *Composite (ZIP)* model or *exponent* model.

For the *Composite (ZIP)* model, coefficient aP specifies the part of total active power load which is constant power, coefficient bP specifies the part of total active power load which is constant current and coefficient $cP = 1 - aP - bP$ specifies the part of total active power load which is constant impedance. For the *Composite (ZIP)* the voltage dependency of loads is given in (3) and (4). The subscript '0' indicates the *Operating Point* values as defined on the Load Flow page of the load element dialog.

$$P = P_0 \left(aP + bP \cdot \left(\frac{v}{v_0} \right) + cP \cdot \left(\frac{v}{v_0} \right)^2 \right) \tag{3}$$

$$Q = Q_0 \left(aQ + bQ \cdot \left(\frac{v}{v_0} \right) + cQ \cdot \left(\frac{v}{v_0} \right)^2 \right) \tag{4}$$

where v is the busbar voltage (p.u.).

For the *Exponent* model, coefficients eP and eQ specify the voltage dependency of the load according to (5) and (6):

$$P = P_0 \cdot \left(\frac{v}{v_0} \right)^{eP} \tag{5}$$

$$Q = Q_0 \cdot \left(\frac{v}{v_0} \right)^{eQ} \tag{6}$$

If the flag *Consider Voltage Dependency of Loads* in the *Load Flow Calculation* command dialog is not selected, a low-voltage load or a partial low-voltage load are always considered to be constant power loads in a load flow calculation.

Note: In *PowerFactory* versions before *2018*, the partial low-voltage load (line load) was considered as a constant current load if the flag *Consider Voltage Dependency of Loads* in the *Load Flow Calculation* command dialog was not selected. To achieve the same load flow results as in previous versions when the flag *Consider Voltage Dependency of Loads* was not selected, the following steps are necessary:

- select the flag *Consider Voltage Dependency of Loads* in the *Load Flow Calculation* command dialog
- assign a low-voltage load type to the partial low-voltage loads (line loads) with voltage dependency specified as ***constant current***
- specify the voltage dependency of all other loads in the system as ***constant power***

The above steps are necessary starting from *PowerFactory 2018* to achieve compatibility with previous versions.

2.3 Balanced Load-Flow

All load elements whose *Technology* is specified as 2-phase or 1-phase are ignored when a balanced load flow is performed.

All three-phase load elements for which unbalanced per-phase load data has been defined, are considered assuming that the total defined power is split equally in the three-phases.

Please refer to Section 2.5 for a description of how the fixed and variable components of the load are taken into consideration.

2.4 Unbalanced Load-Flow

When performing an unbalanced load flow (with a complete ABC-network representation), network unbalances resulting from either unbalanced loads or unbalanced branch elements can be considered.

As mentioned earlier, the low-voltage load and the partial the low-voltage load have their *Technology* specified on the *Basic Data* page of the element. Below are the diagrammatic representations of the various phase technology configurations.

See Section 2.5 for a description of how the fixed and variable components of the load are taken into consideration.

2.4.1 3-phase loads (3PH PH-E, 3PH-'YN')

The actual load per phase is entered on the Load Flow page of the load element dialog. The user has the following choices:

- Balanced load, only specifying the sum of all phases. In this case, it is assumed that the load is shared equally amongst the phases;
- Unbalanced load, specifying the load on a per-phase basis

These configurations are illustrated in Figure 2.2 and Figure 2.3.

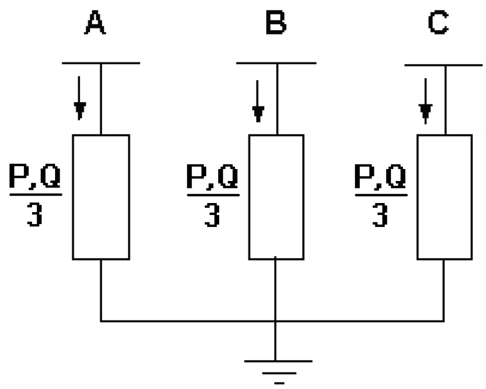

Figure 2.2: 3-phase, Technology 3PH PH-E load model

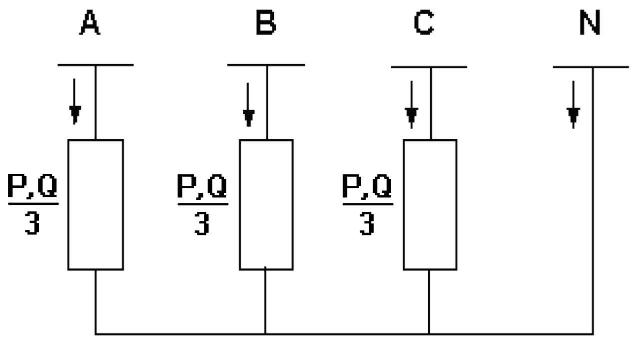

Figure 2.3: 3-phase, Technology 3PH 'YN' load model

2.4.2 2-Phase Loads (2PH-'YN')

This load type can be used for modelling loads in two-phase or bi-phase systems as shown in Figure 2.4.

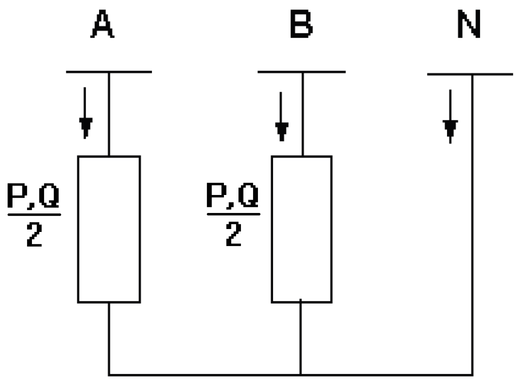

Figure 2.4: 2-phase, Technology 2PH-'YN' load model

2.4.3 1-phase loads (1PH PH-PH, 1PH PH-N, 1PH PH-E)

The 1PH PH-PH load model can be used for representing single-phase loads connected between two phases (see Figure 2.5).

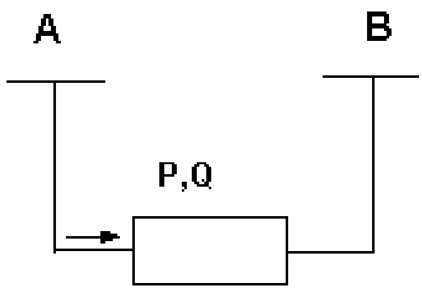

Figure 2.5: 1-phase, Technology 1PH PH-PH load model

The 1PH PH-N load model can be used for a load connected between one phase and the neutral phase (see Figure 2.6).

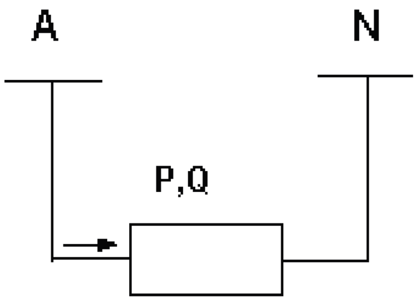

Figure 2.6: 1-phase, Technology 1PH PH-N load model

The 1PH PH-E load model can be used for a load connected between one phase and earth (see Figure 2.7).

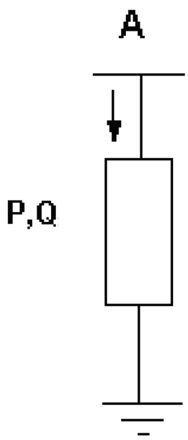

Figure 2.7: 1-phase, Technology 1PH PH-E load model

2.5 Low Voltage Analysis in Load Flow Command

PowerFactory's load flow command dialog offers two options for low-voltage analysis in addition to a dedicated dialog page. These are now described in detail.

The two options are available on the *Basic Data* page of the load flow command dialog in the *Load Options* frame. The first of these options, *Consider Coincidence of Low-Voltage Loads*, calculates a 'low-voltage load flow', where load coincidence factors are considered (for *ElmLodlv* and *ElmLodlvp* objects), so as to produce maximum branch currents and maximum voltage drops. Since coincidence factors are used, the result of this kind of low-voltage analysis will not obey Kirchhoff's current law. After the load flow has been successfully executed, maximum currents (*Imax*), maximum voltage drops (*dumax*) and minimum voltages (*umin*, *Umin*) are displayed on the single line diagram for every branch element and every busbar. The usual currents and voltages calculated represent average values of voltages and currents. Losses are calculated based on average values, and maximum circuit loading is calculated using maximum currents.

The second of these options, *Scaling Factor for Night Storage Heaters*, is also available in the *Load Options* frame, is the factor by which the night storage heater power (as defined in low-voltage load elements) is multiplied for all low-voltage loads.

The load flow command in ***PowerFactory*** also has a *Low Voltage Analysis* page which allows the user to define settings for the analysis of low-voltage systems. It should be noted that the settings on this page are used if there is no type defined in the load element (*ElmLodlv* or *ElmLodlvp*). Sections 2.5.2 and 2.5.3 describe the calculation of all relevant parameters.

The *Definition of Fixed Load per Customer* frame, allows the input of the *Fixed Load* which is the non-stochastic component of the load that is not subject to coincidence factors. The active and reactive power (calculated from the Fixed Load and Power Factor defined in the fields in the Load Flow page) are multiplied by the number of customers (defined in the load elements themselves), and are added to the fixed load defined for each low voltage load (*ElmLodlv* or *ElmLodlvp*).

The *Definition of Variable Load per Customer* frame allows the definition of the variable component of low-voltage loads using the parameters available (average power, max. power per customer, power factor of variable part, and coincidence factor), or by specifically defining LV-load types for the target loads.

2.5.1 Low-Voltage Load Elements without Partial Loads

As stated earlier, the settings on the *Low Voltage Analysis* page in the load flow command are used if there is no type defined in the load element (*ElmLodlv* or *ElmLodlvp*). If the LV-load element has no partial loads defined (see the *Add. Loads* button in the LV-load dialog), the following applies[1]:

Table 2.1: Parameters used in LV analysis

Parameter Name	Description	Obtained from
slini	Fixed apparent power	Element
coslini	Power factor of fixed load	Element

The calculation of relevant quantities in low-voltage analysis is described in Sections 2.5.2 and 2.5.3. The parameters used to calculate these quantities depends on whether or not the low-voltage load elements have types assigned.

2.5.2 Low-Voltage Load Elements with a Type Assigned

If the low-voltage load element (*ElmLodlv*, *ElmLodlvp*) has a type assigned, the variables used for calculation are obtained as shown in Table 2.2.

[1] Variable names are italicized: These are the names that are visible when holding the mouse over the relevant field in ***PowerFactory*** dialogs.

Table 2.2: Parameters used in LV analysis for LV-load elements with a type assigned

Parameter Name	**Description**	**Obtained from**
Smax	Max. Load per Customer	Type
NrCust	No. of Customers	Element
UtilFactor	Utilisation factor	Element
ginf	Coincidence factor	Type
cosphi	Power factor	Type

The *Average Power* per customer is calculated as follows:

$$Sav = Smax \cdot UtilFactor \cdot ginf \cdot NrCust \tag{7}$$

where

- $Smax$ is the *Max. Power per Customer* (the independent maximum power per customer in kVA)

The fixed active power is calculated according to:

$$Pfix = slini \cdot coslini \cdot scale \tag{8}$$

where

- $slini$ is the user-defined apparent power (in kVA) in the element
- $coslini$ is the user-defined power factor in the element
- $scale$ is the scaling factor described in section 2.5.5

The fixed reactive power is calculated according to:

$$Qfix = slini \cdot \sqrt{1 - coslini^2} \cdot scale \tag{9}$$

where

- $slini$ is the user-defined apparent power (in kVA) in the element
- $coslini$ is the user-defined power factor in the element
- $scale$ is the scaling factor described in section 2.5.5

The variable component of the load can be expressed as:

$$S_{variable} = Smax \cdot UtilFactor \cdot (1 - ginf) \cdot \sqrt{NrCust} \tag{10}$$

and the peak power is therefore:

$$S_{peak} = S_{variable} + Sav \tag{11}$$

Finally, the active and reactive power consumed by a load are calculated as:

$$P = (Sav \cdot cos(\varphi) + Pfix) \cdot zonescale \cdot scLoadFac + pnight \tag{12}$$

$$Q = (Sav \cdot sin(\varphi) + Qfix) \cdot zonescale \cdot scLoadFac \tag{13}$$

where

- $sin(\varphi) = \sqrt{1 - cos(\varphi)^2}$
- $zonescale$ is the *Zone Scaling Factor* (if zone and factor are available)
- $scLoadFac$ is the *Load Scaling Factor* of the load flow command
- $pnight$ is the contribution from night storage heaters (if specified)

If additional loads have been defined within an LV-load element, each load is calculated according to that defined by (7), and the sum of these loads is then used in equations (12) and (13).

If the load flow command option *Consider Voltage Dependency of Loads* is enabled, the additional factors (obtained from the voltage dependency coefficients) are considered in (12) and (13).

2.5.3 Low-Voltage Load Elements with no Type Assigned

If the low-voltage load element (*ElmLodlv*, *ElmLodlvp*) has **no** type assigned, the variables used for calculation are obtained as shown in Table 2.3.

Table 2.3: Parameters used in LV analysis for LV-load elements with no type assigned

Parameter Name	**Description**	**Obtained from**
Svar	Max. Load per Customer	Load flow command
NrCust	No. of Customers	Element
UtilFactor	Utilisation factor	Element
ginf	Coincidence factor	Load flow command
cosvar	Power factor	Load flow command
Sfix,*cosfix*	Fixed active power	Load flow command
-	Fixed reactive power	Load flow command

The average power is calculated as:

$$Sav = Svar \cdot UtilFactor \tag{14}$$

The fixed active power is calculated according to:

$$Pfix = (slini \cdot coslini + Sfix \cdot cosfix) \cdot scale \tag{15}$$

where

- $slini$ and $coslini$ are obtained as described in Table 2.1
- $Sfix$ and $cosfix$ are obtained as described in Table 2.3

- $scale$ is the scaling factor described in section 2.5.5

Likewise, the fixed reactive power is calculated according to:

$$Qfix = (slini \cdot \sqrt{1 - coslini^2} + Sfix \cdot \sqrt{1 - cosfix^2}) \cdot scale \tag{16}$$

where

- $slini$ and $coslini$ are obtained as described in Table 2.1
- $Sfix$ and $cosfix$ are obtained as described in Table 2.3
- $scale$ is the scaling factor described in section 2.5.5

The variable component of the load can be expressed as:

$$S_{variable} = Svar \cdot UtilFactor \cdot (1 - ginf) \cdot \sqrt{NrCust} \tag{17}$$

The peak power is calculated according to (11), and the active and reactive power consumed by a load are calculated according to:

$$P = (Sav \cdot cosvar + Pfix) \cdot zonescale \cdot scLoadFac + pnight \tag{18}$$
$$Q = (Sav \cdot sinvar + Qfix) \cdot zonescale \cdot scLoadFac \tag{19}$$

where

- $sinvar = \sqrt{1 - cosvar^2}$
- $zonescale$ is the *Zone Scaling Factor* (if zone and factor are available)
- $scLoadFac$ is the *Load Scaling Factor* of the load flow command
- $pnight$ is the contribution from night storage heaters (if specified)

If additional loads have been defined within an LV-load element, each load is calculated according to (14), and the sum of these loads is then used in equations (18) and (19).

2.5.4 Low-Voltage Load Elements with E, cos(phi) mode

If the low-voltage load element is specified as *E, cos(phi)*, the variables used for calculation are shown in Table 2.4.

Table 2.4: Parameters used in LV analysis for LV-load elements with no type assigned

Parameter Name	**Description**	**Obtained from**
coslini	Power factor	Element
elini	Yearly Energy	Element
pProfile	Consumption Profile	Element

A standard load profile specifies daily power values (in W) in minutes or hours intervals for different days (Saturday, Sunday, and Weekdays) and for different seasons of the year (Summer, Winter and Rest). These values are already normalized, such that when these values are aggregated to a yearly-scale, the total energy consumed for the whole year is exactly 1000 kWh/a.

In *PowerFactory*, the *Consumption Profile* can point to a Season Profile or to a Time Characteristic. The total energy consumed for the whole year in kWh/a can be specified by the user through the *Yearly Energy* field.

The current active and reactive power values are calculated by:

$$P = p(t_i) * \frac{elini}{\sum p(t_i)} \tag{20}$$

$$Q = \sqrt{\frac{P}{coslini} \cdot \frac{P}{coslini} - P \cdot P} \tag{21}$$

Where

- $p(t_i)$ is the value of consumption profile at time t_i.
- $\sum p(t_i)$ is the integral of the season profile or time characteristic for the whole year. In this case, it is irrelevant whether the characteristic is marked as absolute or relative, since it is normalized by equation 20.

2.5.5 Fixed Power Scale Factor

No Feeder Scaling

When there is no external scaling by the corresponding feeder, the value $scale$ is simply:

$$scale = \textit{scale0} \tag{22}$$

where *scale0* is the parameter *Scaling Factor* defined in the Load Flow page.

Feeder Scaling

In order to allow scaling by the corresponding feeder, the following conditions must apply:

- Parameter *Adjusted by Load Scaling* must be selected
- Parameter *Feeder Load Scaling* in the Load Flow command must be selected
- Parameters *Scaling Factor* and *Power Factor* in the feeder dialog must be different from ”No Scaling”

Feeder Scaling with Scaling Factor Only

In the case of feeder scaling with the parameter *Scaling Factor* different from ”No Scaling” and the parameter *Power Factor* equal to ”No Scaling”, the values $scale$ is calculated by the feeder.

Feeder Scaling with Power Factor Scaling

In the case of feeder scaling with the parameter *Power Factor* different from ”No Scaling”, the values of fixed power are recalculated according to the following:

$$Sfix = \sqrt{Pfix^2 + Qfix^2} \tag{23}$$
$$Pfix = Sfix \cdot cos(phi) \tag{24}$$
$$Qfix = Sfix \cdot sin(phi) \tag{25}$$
$$\tag{26}$$

where phi is calculated by the feeder.

2.5.6 Voltage Drop Analysis

The *Voltage Drop Analysis* frame provides a selection of two calculation methods for the consideration of the stochastic nature of loads:

- Stochastic Evaluation
- Maximum Current Estimation

The *Stochastic Evaluation* method is the more theoretical approach of the two and can also be applied to meshed network topologies. The *Maximum Current Estimation* method applies stochastic rules only for the estimation of maximum branch flows. Based on the maximum current flow in each branch element, maximum voltage drops are calculated and added along the feeder. This method has its limitations in cases of meshed LV networks.

3 Short-Circuit Analysis

Short-circuit calculations according to IEC 60909, VDE102/103 or ANSI C37 generally neglect loads and only consider motor contributions. The IEC 61363 method ignores loads when calculating the short-circuit contribution, however if the calculation option *Preload Condition* (available on the Advanced Options page in the Short-Circuit Calculation dialog) is set to use load flow initialization, loads are considered in the load flow calculation to calculate pre-fault voltages and currents. These pre-fault voltages and currents are then considered in the short-circuit calculation.

The Complete short-circuit method utilises constant impedance (Z) or constant current (I_0) models for consideration of the load flow current. Z and I_0 are calculated from a preceding load flow analysis.

The Low-Voltage Load is modelled as a constant impedance on the Complete Short-Circuit. Depending on whether the load is purely capacitive or purely inductive, either the resistance and inductance are calculated or the capacitance and conductance are calculated. The load admittance is calculated as follows:

$$Y_{load} = I(ldf)/U(ldf)$$

where

- $I(ldf)$ is the load flow current
- $U(ldf)$ is the load flow voltage

The load current is set to zero:

$$Iload = 0$$

Figure 3.1 illustrates the constant impedance load in Y- configuration.

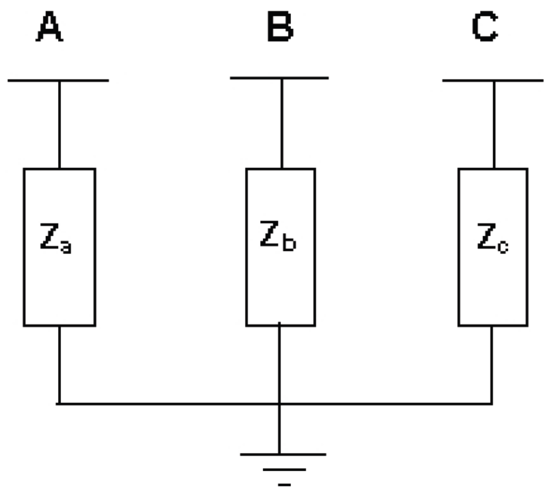

Figure 3.1: 3-phase constant impedance model, in Y-connection, used by the Complete Short-Circuit calculation method

4 Harmonic Analysis

In harmonic analysis, the Low-Voltage Load is modelled as an impedance, which is purely inductive/capacitive. Figure 4.1 shows the single-phase representations of a purely inductive and a purely capacitive load.

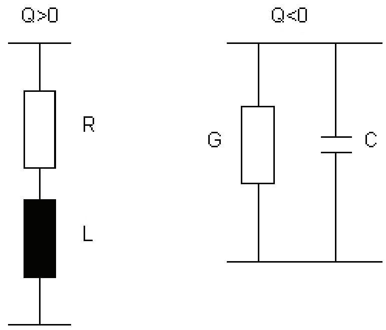

Figure 4.1: Purely inductive/capacitive load models used for harmonic analysis

The parameters R,L (G,C) are calculated from a preceding load flow.

5 RMS Simulation

For RMS simulations, the low-voltage load and the partial low-voltage load are modelled as a constant impedance.

When running an unbalanced RMS simulation initialized with a balanced load flow, the behaviour of a three-phase low-voltage load (or partial low-voltage load) with unbalanced power definition depends on whether it is initially connected or it is connected during the simulation. The initially connected load will be assumed balanced (since a balanced load flow is used for initialization), while the load connected during the simulation will be considered unbalanced (according to the user definition).

6 EMT Simulation

In EMT simulations the low-voltage load and the partial low-voltage load are modelled as a passive load, which is purely inductive/capacitive.

When running an EMT simulation initialized with a balanced load flow, the behaviour of a three-phase low-voltage load (or partial low-voltage load) with unbalanced power definition depends on whether it is initially connected or it is connected during the simulation. The initially connected load will be assumed balanced (since a balanced load flow is used for initialization), while the load connected during the simulation will be considered unbalanced (according to the user definition).

7 Reliability

In reliability calculations, low-voltage loads are considered in exactly the same manner as general loads. Partial LV-loads (*ElmLodlvp*) require no input of data for reliability calculations. Please refer to the corresponding chapter of the ***PowerFactory*** manual for a detailed description of the calculated reliability indices.

To allow the consideration of load-shedding for transmission or distribution systems, the *Network* option in the reliability command dialog is provided.

When option *Distribution (Sectionalising, Switching actions)* is selected, whole loads are disconnected by switching (according to each load's assigned *Priority*), and there are no shedding steps involved. However, when option *Transmission (Gen. Re-dispatch, Load-Transfer/-Shedding)* is selected, loads are shed in steps according to each load's assigned *Priority* and *Shedding steps*. Loads with the lowest *Priority* will be shed first, regardless of their active power demand. The *Shedding steps* define how the aggregate load will be divided and shed. The selection of an *infinite* number of shedding steps means that shedding will take place on an 'as-required' basis.

A percentage of any load may be defined as being *Transferable*, meaning that this percentage of the load can be transferred to another load. An *Alternative Supply* may optionally then be defined, which must be an existing general load (*ElmLod*) or LV-load element (*ElmLodlv*). The defined percentage of the load is then transferred to that supply, and overloading is checked. If no *Alternative Supply* has been specified, the load will still be transferred, and it is assumed by ***PowerFactory*** that the load has been shifted to a feeder which is not modelled. This is functionally identical to load-shedding but with no associated costs.

The *Interruption Costs* frame is used for the definition of interruption costs via a *Time dependent rate*, a *Scaling factor* and the *Unit* for the costs. The *Time dependent rate* is input using a parameter characteristic, and the costs calculated from this rate are multiplied with the *Scaling factor* to get the interruption costs. The calculation of the interruption costs is calculated by first calculating the rate from the time dependent rate and the interruption duration (for a single load, i, and a single case, c), as shown in (27). (It should be noted that in ***PowerFactory***, a 'load point' is defined as the load itself).

$$Ta_{c,i} = f(T_{c,i}) \tag{27}$$

The load point interruption costs (LPIC) are calculated as follows if the selected units are in $\$/kW$:

$$LPIC_{c,i} = LPPNS_{c,i} \cdot Ta_c \cdot m_i \tag{28}$$

or as follows if the units are in $\$$/customer:

$$LPIC_{c,i} = LPCNS_{c,i} \cdot Ta_c \cdot m_i \tag{29}$$

or as follows if the units are in $\$$:

$$LPIC_{c,i} = Ta_c \cdot m_i \tag{30}$$

where

- i is the load index
- c is the case index
- $T_{c,i}$ is the load interruption duration

- m_i is the cost scaling factor per load
- $LPPNS_{c,i}$ is the load point power not supplied (in MW)
- $LPCNS_{c,i}$ is the load point customers not supplied
- Ta is the tariff
- $LPIC_{c,i}$ is the load point interruption cost (in $\$$)

All general loads and low-voltage loads can be classified according to the *Load Classification* as either *Agricultural*, *Domestic*, *Commercial*, *Industrial*, or another user-defined classification. This classification has no bearing upon the reliability calculation, and is provided for categorization purposes only.

8 Parameters Definition

8.1 Low-Voltage Load Element

Table 8.1: Input parameters for low-voltage load element (*ElmLodlv*)

Parameter	Unit	Default Value	Description	Range
lodparts			Add. Loads	
loc_name			Name	
typ_id			Type (TypLodlv)	
bus1			Terminal (StaCubic)	
bus1_bar			Terminal	
cpZone			Zone	
cpArea			Area	
outserv		0	Out of Service	x≥0 and x≤1
phtech		3PH PH-E	Technology	
iopt_inp		0	Fixed Load: Load Type	x≥0 and x≤3
ulini	kV	0,4	Fixed Load: Voltage, U(L-L)	x>0
plini	kW	0,	Fixed Load: Active Power, P	
slini	kVA	0,	Fixed Load: Apparent Power, S	x≥0
ilini	A	0,	Fixed Load: Current, I	x≥0
coslini		0,	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1
pf_recap		ind.	Fixed Load: Power Factor	ind.:cap.
elini	kWh	0	Yearly Energy	x≥0
pProfile			Consumption Profile	
scale0		1,	Fixed Load: Scaling Factor	
i_scale		0	Fixed Load: Adjusted by Load Scaling	x=0 or x=1
i_sym		0	Balanced/Unbalanced	
plinir	kW	0,	Fixed Load: Active Power, P	
slinir	kVA	0,	Fixed Load: Apparent Power, S	x≥0
ilinir	A	0	Fixed Load: Current, I	x≥0
coslinir		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1
pf_recapr		ind.	Fixed Load: Power Factor	ind.:cap.
plinis	kW	0	Fixed Load: Active Power, P	
slinis	kVA	0	Fixed Load: Apparent Power, S	x≥0
ilinis	A	0	Fixed Load: Current, I	x≥0
coslinis		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1
pf_recaps		ind.	Fixed Load: Power Factor	ind.:cap.
plinit	kW	0	Fixed Load: Active Power, P	
slinit	kVA	0,	Apparent Power, S	x≥0
ilinit	A	0	Fixed Load: Current, I	x≥0
coslinit		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1
pf_recapt		ind.	Fixed Load: Factor	ind.:cap.
pnight	kW	0,	Night Storage Heater: P	x≥0
NrCust		0	Variable Load: Number of Customers	x≥0
cPrCust	kW	0,	Variable Load: P/Customer	
UtilFactor		1,	Variable Load: Utilisation Factor	x≥0
cSmax	kVA	0,	Variable Load: Max. Load	

cSav	kVA	0,	Variable Load: Average Load	
ccosphi		0,95	Variable Load: Power Factor	
cHasPartLod		0	Partial Loads Present	
cPartLod			Partial Loads:	
ulini_a	kV	0,4	U(L-L)(act.)	
plini_a	kW	0,	P(act.)	
qlini_a	kvar		Q(act.)	
slini_a	kVA	0,	S(act.)	
coslini_a		0,	cos(phi)(act.)	
ilini_a	A	0,	I(act.)	
scale0_a		1,	Scaling Factor(act.)	
pnight_a	kW	0,	P(night)(act.)	
i_prty		0	Priority	
shed		0	Load shedding/transfer (Transmission Option): Shedding steps	infinite:1:2:3:4:5:6:-7:8:9:10
trans	%	0,	Load shedding/transfer (Transmission Option): Transferable	x≥0.0 and x≤100.0
cTrans	%	0,	Load shedding/transfer (Transmission Option): Resulting	

Table 8.2: Input parameters for low-voltage load element (*ElmLodlv*)

Parameter	Unit	Default Value	Description	Range
pTrans			Load shedding/transfer (Transmission Option): Alternative Supply (Load) (ElmLod,ElmLodlv)	
pSCDF			Interruption costs: Time dependent rate (ChaVec,ChaOut)	
fSCDF		1,	Interruption costs: Scaling factor	
OptCost		$/kW	Interruption costs: Unit	
classif			Load Classification	Agricultural:-Domestic:-Commercial:-Industrial
gnrl_modif		01.01.1970 01:00:00	Object modified	
gnrl_modby			Object modified by	
sernum			Serial Number	
constr		0	Year of Construction	
iComDate		01.01.1970 01:00:00	Commissioning Date	
chr_name			Characteristic Name	
for_name			Foreign Key	
dat_src		MAN	Data source	
doc_id			Additional Data ()	
pOwner			Owner (ElmOwner)	
pOperator			Operator (ElmOperator)	
desc			Description	
appr_status		Not Approved	Approval Information: Status	
appr_modif		01.01.1970 01:00:00	Approval Information: Modified	
appr_modby			Approval Information: Modified by	
cimRdfId			RDF ID	
dpl1		0,	dpl1	
dpl2		0,	dpl2	
dpl3		0,	dpl3	
dpl4		0,	dpl4	
dpl5		0,	dpl5	

8.2 Partial LV-Load Element

Table 8.3: Input parameters for partial LV-load element (*ElmLodlvp*)

Parameter	Unit	Default Value	Description	Range	Symbol
loc_name			Name		
typ_id			Type (TypLodlv)		
outserv		0	Out of Service	x≥0 and x≤1	
lneposkm	km	0,	Position on Line		
lnepos	%	50,	Position on Line	x≥0 and x≤100	
iopt_inp		0	Fixed Load: Load Type	x≥0 and x≤3	
ulini	kV	0,4	Fixed Load: Voltage, U(L-L)	x>0	v_0
plini	kW	0	Fixed Load: Active Power, P		P_0
slini	kVA	0	Fixed Load: Apparent Power, S	x≥0	
ilini	A	0	Fixed Load: Current, I	x≥0	
coslini		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1	
pf_recap		ind.	Fixed Load: Power Factor	ind.:cap.	
i_sym		0	Balanced/Unbalanced		
plinir	kW	0,	Fixed Load: Active Power, P		
slinir	kVA	0,	Fixed Load: Apparent Power, S	x≥0	
ilinir	A	0	Fixed Load: Current, I	x≥0	
coslinir		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1	
pf_recapr		ind.	Fixed Load: Power Factor	ind.:cap.	
plinis	kW	0	Fixed Load: Active Power, P		
slinis	kVA	0	Fixed Load: Apparent Power, S	x≥0	
ilinis	A	0	Fixed Load: Current, I	x≥0	
coslinis		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1	
pf_recaps		ind.	Fixed Load: Power Factor	ind.:cap.	
plinit	kW	0	Fixed Load: Active Power, P		
slinit	kVA	0,	Apparent Power, S	x≥0	
ilinit	A	0	Fixed Load: Current, I	x≥0	
coslinit		1	Fixed Load: Power Factor, cos(phi)	x≥-1 and x≤1	
pf_recapt		ind.	Fixed Load: Factor	ind.:cap.	
pnight	kW	0,	Night Storage Heater: P	x≥0	
NrCust		0	Variable Load: Number of Customers	x≥0	
cPrCust	kW	0,	Variable Load: P/Customer		
UtilFactor		1,	Variable Load: Utilisation Factor	x≥0	
$cSmax$	kVA	0	Variable Load: Max. Load		
cSav	kVA	0,	Variable Load: Average Load		
ccosphi		0,95	Variable Load: Power Factor		
ulini_a	kV	0,4	U(L-L)(act.)		
plini_a	kW	0,	P(act.)		
qlini_a	kvar		Q(act.)		
slini_a	kVA	0,	S(act.)		
coslini_a		0,	cos(phi)(act.)		
ilini_a	A	0,	I(act.)		
pnight_a	kW	0,	P(night)(act.)		
gnrl_modif		01.01.1970 01:00:00	Object modified		
gnrl_modby			Object modified by		

sernum			Serial Number		
constr		0	Year of Construction		
iComDate		01.01.1970 01:00:00	Commissioning Date		
chr_name			Characteristic Name		
for_name			Foreign Key		
dat_src		MAN	Data source		
doc_id			Additional Data ()		
pOwner			Owner (ElmOwner)		
pOperator			Operator (ElmOperator)		
desc			Description		
appr_status		Not Approved	Approval Information: Status		
appr_modif		01.01.1970 01:00:00	Approval Information: Modified		
appr_modby			Approval Information: Modified by		

8.3 Low-Voltage Load Type

Table 8.4: Input parameters for low-voltage load type (*TypLodlv*)

Parameter	Unit	Default Value	Description	Range
loc_name			Name	
Smax	kVA	12,	Max. Load per Customer	x≥0
cosphi		0,95	Power Factor	x≥0
ginf		0,1	Coincidence Factor ginf	x≥0
iLodTyp		0	Load model: ZIP/Exponent	x=0 or x=1
eQ		1	Exponent eQ	x≥0
eP		1	Exponent eP	x≥0
aP		0	Coefficient aP	x≥0 and x≤1
bP		1	Coefficient bP	x≥0 and x≤1
cP		0	Coefficient cP	x≥0 and x≤1
aQ		0	Coefficient aQ	x≥0 and x≤1
bQ		1	Coefficient bQ	x≥0 and x≤1
cQ		0	Coefficient cQ	x≥0 and x≤1
gnrl_modif		01.01.1970 01:00:00	Object modified	
gnrl_modby			Object modified by	
manuf			Manufacturer	
chr_name			Characteristic Name	
for_name			Foreign Key	
dat_src		MAN	Data source	
doc_id			Additional Data ()	
desc			Description	
appr_status		Not Approved	Approval Information: Status	
appr_modif		01.01.1970 01:00:00	Approval Information: Modified	
appr_modby			Approval Information: Modified by	

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