# Simplified selection procedure

**For a detailed Selection Guide, please refer to ABB publications PTHVP/A 2300E and PTHVP/A 2310E.**

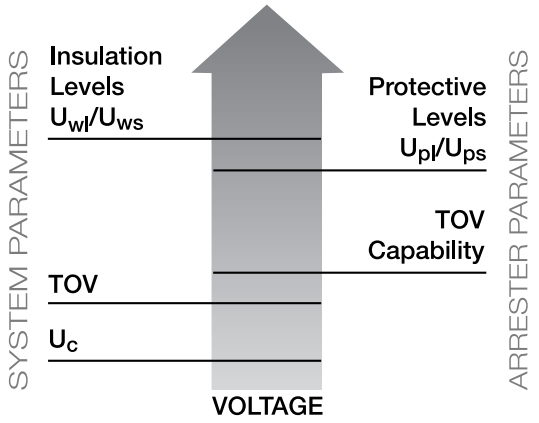
**The catalogues list the available standard arresters from ABB of porcelain-housed arresters type EXLIM and silicone polymer-housed arresters, type PEXLIM.**

The selection is carried out in two major steps:

- Matching the electrical characteristics of the arresters to the system's electrical demands
- Matching the mechanical characteristics of the arresters to the system's mechanical and environmental requirements.

The final selection is reflected in the arrester type designation.

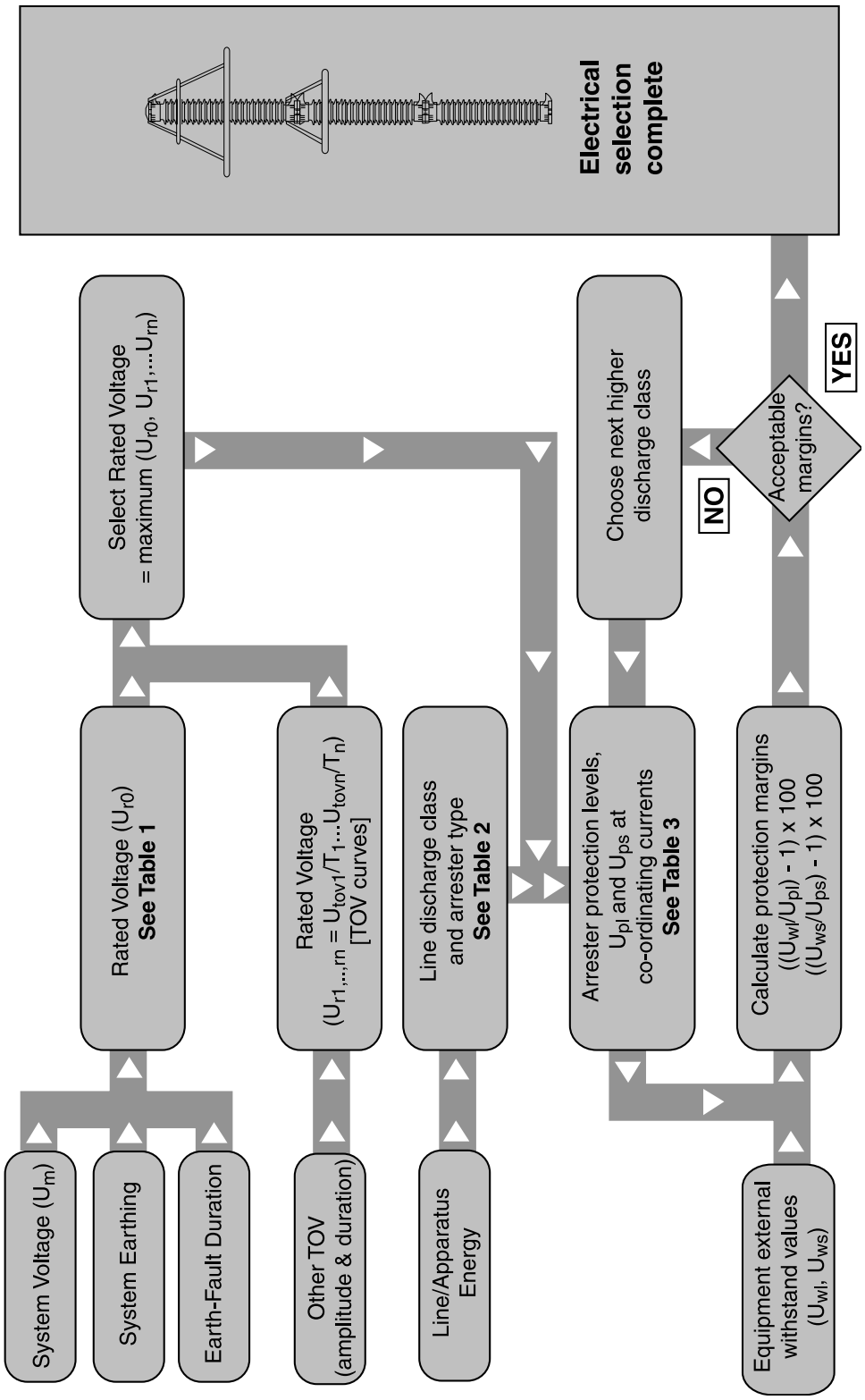
## Vocabulary




| | |
|---|---|
| $U_m$ | Maximum system voltage |
| $U_c$ | Continuous operating voltage |
| $U_r$ | Rated voltage |
| TOV | Temporary overvoltage |
| T | TOV strength factor |

| | |
|---|---|
| k | Earth fault factor |
| $U_{ps}$ | Switching impulse protective level |
| $U_{pl}$ | Lightning impulse protective level |
| $U_{ws}$ | Switching impulse withstand level |
| $U_{wl}$ | Lightning impulse withstand level |

# Flowchart for simplified selection of surge arresters



# Matching the electrical characteristics

### Arrester rated voltage ($U_r$)

For each system voltage, the tables "Guaranteed protective data" show a range of $U_r$ and maximum continuous operating voltages $U_c$, all of which are capable of withstanding the actual continuous operating voltage ($U_{ca}$) with sufficient margin. Hence, the selection of $U_r$ is only a function of the applied temporary overvoltages, TOV, ($U_{tov}$), taking into account their amplitudes and duration.

TOV are long-duration, mostly power-frequency (p.f.) or nearly p.f. voltages, with or without harmonics, generated by system events. The arresters must withstand the heat energy generated by them.

Most commonly, a single or two-phase earth fault leads to a TOV in the healthy phase(s) and also in the neutral of Y-connected transformers. Its amplitude is determined by the system earthing conditions and its duration by the fault-clearance time.

If the earth-fault factor, (k) = $U_{tov}/U_{ca}$, is 1.4 or less, the system is considered to be effectively earthed. Generally, this implies a solid connection of the neutral to the earth grid. All other forms of earthing via an impedance or a non-earthing of the neutral is considered as non-effective with k = 1.73

For effectively earthed systems, the fault-clearance time is generally under 1 s but it can vary widely among different systems. The catalogues list the values of TOV capability for 1 and 10 s duration after a prior energy stress (as a conservative approach). For other durations or for specific TOV conditions, follow the procedure hereunder:

- Consider each TOV separately.
- From the TOV curves, read off the TOV strength factor (T) for the time corresponding to the fault-clearance time.
- $U_{tov}/T$ gives the min. value of $U_r$ for withstanding this TOV. Choose the next higher standard rating.
- The final choice of $U_r$ will be the highest of the $U_r$ values obtained from the above calculations for each TOV.

| System Earthing | Fault Duration | System Voltage $U_m$ (kV) | Min. Rated Voltage, $U_r$ (kV) |
|---|---|---|---|
| Effective | ≤ 1 s | ≤ 100 | ≥ 0.8 x $U_m$ |
| Effective | ≤ 1 s | ≥ 123 | ≥ 0.72 x $U_m$ |
| Non-effective | ≤ 10 s | ≤ 170 | ≥ 0.91 x $U_m$<br>≥ 0.93 x $U_m$ (EXLIM T) |
| Non-effective | ≤ 2 h | ≤ 170 | ≥ 1.11 x $U_m$ |
| Non-effective | > 2 h | ≤ 170 | ≥ 1.25 x $U_m$ |

**Table 1.**
The table gives a minimum value of the arrester rated voltage ($U_r$). In each case, choose the next higher standard rating as given in the catalogue.

> Note: Do not select a lower value of $U_r$ than obtained as above unless the parameters are known more exactly; otherwise the arrester may be overstressed by TOV.

### Energy capability & line discharge class

IEC classifies arresters by their nominal discharge current. For 10 and 20 kA arresters, they are also classified by energy capability expressed as line discharge class (2 to 5) verified in a long duration current test and a switching surge operating duty test. In the latter, the arrester is subjected to two impulses of a given amplitude and duration after which it must be thermally stable against $U_C$. The "class" figure roughly gives the expected energy absorbed in kJ/kV ($U_r$) per impulse. As seen in Table 2, the ABB arresters are tested for a much higher energy absorption capability.

| Arrester Type | Line discharge class | Energy capability (2 impulses) kJ/kV ($U_r$) | Normal application range ($U_m$) |
|---|---|---|---|
| EXLIM R | 2 | 5.0 | ≤ 170 kV |
| PEXLIM R | 2 | 5.1 | ≤ 170 kV |
| EXLIM Q | 3 | 7.8 | 170 - 420 kV |
| PEXLIM Q | 3 | 7.8 | 170 - 420 kV |
| EXLIM P | 4 | 10.8 | 362 - 550 kV |
| PEXLIM P | 4 | 12 | 362 - 550 kV |
| HS PEXLIM P | 4 | 10.5 | 362 - 550 kV |
| EXLIM T | 5 | 15.4 | 420 - 800 kV |
| HS PEXLIM T | 5 | 15.4 | 420 - 800 kV |

**Table 2.**
Energy capability of ABB arresters: The normal application range is only a guide. Arresters for higher class may be required depending on the specific parameters.

# Matching the electrical characteristics

Though the energy capability is mentioned in a different manner in ANSI, the normal range of application as above applies even for ANSI systems.

For specific and special cases, e.g. capacitor banks, it may be necessary to calculate the energy capability as shown in the IEC 60099-5 and other guides, e.g. publication PTHVP/A 2312en.

## Protection levels ($U_{pl}$ and $U_{ps}$)

For insulation co-ordination purposes, consider the lightning impulse protection level ($U_{pl}$) at 10 kA for $U_m \leq 362$ kV and at 20 kA for higher voltages. Similarly, the switching impulse protection levels ($U_{ps}$) for co-ordination purposes range from 0.5 kA (for $U_m \leq 170$ kV) to 2 kA (for $U_m \geq 362$ kV). The values can be read-off from the catalogue tables or easily computed from Table 3. *In the latter case, they must be rounded upwards.*

| Arrester Type | Nom. Discharge current ($I_n$) | $U_{pl}/U_r$ at 10 $kA_p$ | $U_{pl}/U_r$ at 20 $kA_p$ | $U_{ps}/U_r$ |
|---|---|---|---|---|
| EXLIM R | 10 | 2.590 | | 2.060 at 0.5 $kA_p$ |
| PEXLIM R | 10 | 2.590 | | 2.060 at 0.5 $kA_p$ |
| EXLIM Q | 10 | 2.350 | | 1.981 at 1.0 $kA_p$ |
| PEXLIM Q | 10 | 2.350 | | 1.981 at 1.0 $kA_p$ |
| EXLIM P | 20 | 2.275 | 2.5 | 2.020 at 2.0 $kA_p$ |
| PEXLIM P | 20 | 2.275 | 2.5 | 2.020 at 2.0 $kA_p$ |
| HS PEXLIM P | 20 | 2.275 | 2.5 | 2.020 at 2.0kAp |
| EXLIM T | 20 | 2.200 | 2.4 | 1.976 at 2.0 $kA_p$ |

**Table 3.**
$U_{pl}$ and $U_{ps}$ ratios for ABB arresters

## Protection margins

Protection margins (in %), calculated at co-ordinating impulse currents as per Table 3, are defined as follows:

- Margin for lightning impulses = $((U_{WI}/U_{pl})-1) \times 100$, where $U_{WI}$ is the external insulation withstand of the equipment against lightning impulses.
- Margin for switching impulses = $((U_{WS}/U_{ps})-1) \times 100$ where $U_{WS}$ is the external insulation withstand of the equipment for switching impulses.

Note! ANSI standards refer to $U_{wl}$ as BIL and $U_{ws}$ as BSL.

Margins are normally excellent due to the low $U_{pl}$, $U_{ps}$ and also that most equipment at present have a high $U_{wl}$ and $U_{ws}$. However, depending on the electrical distance between the arrester and the protected equipment, the $U_{pl}$ margin is reduced and thus arresters fail to protect equipment that is not in the close vicinity of the arresters (i.e. within their protection zone). The flexible erection alternatives for PEXLIM arresters may be of benefit in reducing the distance effects. Additional line-entrance arresters may help too. For more detailed information regarding this, please refer to publications PTHVP/A 2310E and PTHVP/A 2120en.

Note! The ”distance effect” reduction does not apply to $U_{ps}$ margin since the front-time of a switching surge impulse is longer.

It is recommended that the protection margins (after taking into account the ”distance effect”) should be of the order of 20% or more to account for uncertainties and possible reduction in the withstand values of the protected equipment with age.

Should the selected arrester type not give the desired protection margins, the selection should be changed to an arrester of a higher line discharge class, which automatically leads to lower $U_{pl}$.

Note! Do NOT use a lower-than selected ($U_r$) to attempt improve the margins, as this may lead to unacceptably low TOV capability.

As an additional assistance in selection, please refer to the simplified flow chart at the beginning of this chapter.

# Matching the mechanical characteristics

The varistor column must be suitably housed to withstand long-term effects of the system loading and the environmental stresses.

### External creepage distance

IEC 60815 defines the minimum creepage distances for different environmental conditions. Select the housing to give the desired creepage - the same as for the other equipment in the same location. If the creepage demand exceeds 31 mm/kV, please refer to ABB for a special design.

PEXLIM arresters, having a highly hydrophobic housing, are better suited for extremely polluted areas than EXLIM arresters and a lower creepage may be justified in many cases.

### Mechanical strength

The maximum useable static and permissible cantilever loading is shown in the relevant catalogues and summarised in Table 4.

Since arresters do not carry any large continuous current, they should be provided with lighter leads and clamps to reduce the static loading. Suspending PEXLIM arresters further reduces the static terminal loading and allows PEXLIM arresters to also be chosen for higher voltages without mechanical problems.

For short arresters, the mechanical strength of PEXLIM approximately equals that for EXLIM. For longer arresters, the lower mechanical strength of PEXLIM arresters can be compensated by using suspended or under-hung erection or by special bracing for upright erection. For details, refer to publication PTHVP/A 2120en.

Mechanical test of silicone-housed arrester PEXLIM P.

| Arrester type | Cantilever strength (Nm) | | |
|---|---|---|---|
| | MPDSL | PSSL | DPSSL |
| EXLIM R-C | 7 500 | 3 000 | n.a. |
| EXLIM Q-D | 18 000 | 7 200 | n.a. |
| EXLIM Q-E | 7 500 | 3 000 | n.a. |
| EXLIM P-G | 18 000 | 7 200 | n.a. |
| EXLIM T-B | 18 000 | 7 200 | n.a. |
| PEXLIM R-Y | 1 600 | n.a. | 1 000 |
| PEXLIM Q-X | 4 000 | n.a. | 2 500 |
| PEXLIM P-X | 4 000 | n.a. | 2 500 |
| HS PEXLIM P | 28 000 | n.a. | 19 000 |
| HS PEXLIM T | 28 000 | n.a. | 19 000 |

**Table 4.**
Permissible strength loading for ABB arresters

MPDSL - Maximum permissible dynamic service load.

PSSL - Permissible static service load (for PEXLIM arresters this is a declared value based on cyclic loading).

DPSSL - Declared permissible static service load.

# Simplified selection procedure

### Neutral-ground arresters

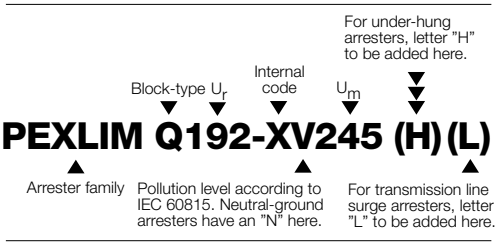
For neutral-ground arresters the recommended rated voltage is approximately the maximum system voltage divided by √3. The recommended neutral-ground arresters in the relevant sections are calculated for unearthed systems with relatively long fault duration. The electrical characteristics are identical to standard catalogue arresters with the corresponding rated voltage. For such arresters, $U_C$ is zero and they are not subject to any voltage stress during normal service conditions. The neutral-ground arresters should preferably be of the same type as the phase-ground arresters. For resonant-earthed systems with long radial lines special considerations must be taken. A higher rated voltage (20% to 40%) than listed may be necessary.

### Type designation

The type designation itself gives detailed information of the arrester and its application. See the figure below. As standard, the arresters are meant for upright vertical erection. For under-hung erection, when desired, the type designation is completed by letter "H" after system voltage ($U_m$). For other angular erection, please inform us at order.

For non-standard arresters, the type designation will have additional letters for example:

| | |
|---|---|
| **E** | **Non-standard electrical data** |
| **M** | **Non-standard mechanical data** |
| **P** | **Parallel metal-oxide columns** |




### Special applications

Please consult your nearest ABB representative for help in selection of arresters for special applications such as protection of shunt or series capacitor banks, cables and cable-aerial junctions, rotating machines, traction systems, overhead lines, HVDC etc. or for non-standard arrester ratings.

### Ordering data for arresters

The following information, at a minimum, is required with your order:

- Quantity and type designation
- Rated voltage
- Type of line terminal
- Type of earth terminal
- Type of surge counter, if any
- Type of insulating base, if any.

(Insulating base is required if surge counter and/or leakage current measurements are desired. One base is required for each arrester).

### Ordering example

Below is a typical example of an order with three PEXLIM arresters and its accessories.

| | |
|---|---|
| 3 pcs. | PEXLIM Q192-XV245<br>Rated voltage 192 kV<br>Line terminal type 1HSA 410 000-L<br>Earth terminal type 1HSA 420 000-A |
| 3 pcs. | Insulating base type 1HSA 430 000-A |
| 3 pcs. | Surge counter type EXCOUNT-A |

Note! We recommend that the order form, in section T-1, be filled-in and attached to your order to ensure inclusion of all the important parameters and commercial conditions.

# Simple selection example

| **Substation data:** | |
|---|---|
| Maximum system voltage: | 145 kV |
| Arrester location: | Phase-ground |
| System earthing: | Effective |
| System fault clearance time: | 1 s |
| Creepage distance: | 3 000 mm |

**1** $U_{r0}$ = 0.72x$U_m$ (according to table 1) = 0.72x145 = 104.4 $kV_{rms}$. Select the next higher standard $U_r$ (see "Guaranteed protective data"), i.e. 108 $kV_{rms}$.

**2** According to table 2, a common choice selection for 145 $kV_{rms}$ would be a line discharge class 2 arrester, i.e. PEXLIM R. This arrester has a $U_{pl}/U_r$ of 2.59, i.e. $U_{pl}$ of 280 $kV_{peak}$ at 10 kA (according to table 3). With a $U_{wl}$ of 550 $kV_{peak}$ this would give a protective margin of (550/280-1)x100 = 96 %.

**3** This margin appears to be excellent but it must be noted that depending on distance effect and possible insulation ageing, the margin is reduced to only 10% to 15% after taking distance effect into account and depending on the chosen impulse steepness and amplitude. Thus, it is very important that the arrester is installed as close as possible to the protected object.

**4** If the margin is considered insufficient, choose a class 3 arrester, e.g. PEXLIM Q with the same rated voltage 108 kV.

**5** With a required creepage distance of 3 000 mm, i.e. 20.7 mm/kV, YH145 (XH145 for PEXLIM Q) housing should be selected.

**6** The type designation of the selected arrester will then be:

**PEXLIM R108-YH145**
**(or PEXLIM Q108-XH145)**