Technical information

Installation of instrument transformers at high altitude
Effects, problems and solutions

To reduce the risk of insulation failure to an economically and operationally acceptable level, it is important that the insulation withstand of substation equipment should be selected with regard to the expected over-voltages occurring during the normal operation of the substation. Important in this aspect is of course the protection characteristics of the installed surge arresters.

Since the air pressure is lower at high altitudes, the dielectric strength of components will be lower. For this reason, longer insulators may be needed.

For high altitude installations the thermal behavior and the withstand voltage for the external insulation of the instrument transformers are affected by the reduction of air density.

Current transformer IMB 145

Service conditions for instrument transformers are in IEC 61869-1 divided into two groups:

1. Normal service conditions.
This group considers installation at an altitude below 1000 m. Normal limit for temperature rise and standard insulation levels as per IEC 61869-1 table 2 are applicable.

2. Special service conditions.
This group considers installation at an altitude above 1000 m, installation in areas with daily average temperature of more than 35 °C and areas with seismic activity.

The reduction of air density at high altitude installations means that the cooling ability of the air is reduced and temperature rise limits of internal parts of the instrument transformer, for installation at an altitude above 1000 m, must be reduced. The reduction factor for oil immersed instrument transformers is 0.4% per 100 m above 1000 m

Altitude correction for external insulation
ABB makes the needed design modifications

Altitude correction for external insulation

The reduced air density at high altitude installations has an effect on the disruptive voltage of the external insulation. For installations at an altitude higher than 1000 m, the arcing distance under the standardized reference atmospheric conditions shall be determined by multiplying the withstand voltages required at the service location by a factor k in accordance with Figure 2 of IEC 61869-1.

The dielectric strength of the internal insulation is not affected by the altitude.

The correction factor for external insulation is per IEC 61869-1 according to the formula:

$$k = e^{\frac{m\,(H-1000)}{8150}}$$

m = 1.0 for power frequency voltage and LIWL and 0.75 for SIWL
H = altitude above sea level in meters.

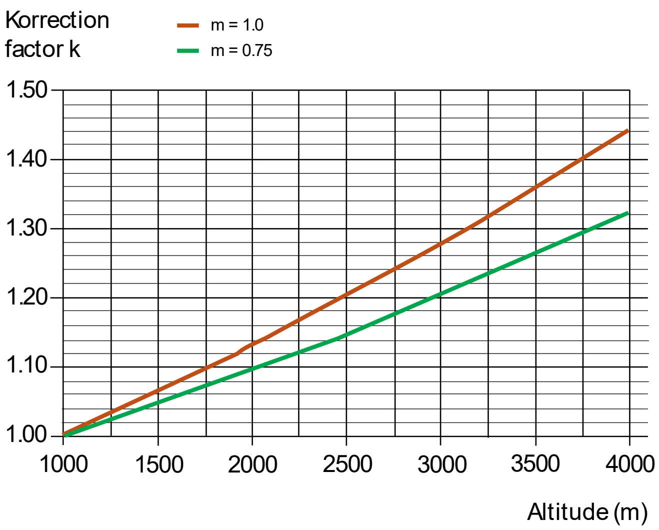


Figure 2. Altitude correction factor for external insulations level

From Figure 2 it can be concluded that an instrument transformer intended for installation at an altitude of 3000 m shall have an external flashover distance able to, at altitude <1000 m, withstand a voltage of approximate 1.28 times the standardized withstand voltages.

Critical voltages for the external insulation is for system voltages <300 kV the wet power frequency voltage withstand test voltage and for system voltages ≥300 kV the wet switching impulse test voltage.

A number of limit tests have been made to establish the withstand level of external insulation. For the wet power frequency voltage withstand of the external insulation tests have been made on 145 kV and 245 kV insulators and both tests show the same withstand expressed as kV/mm flashover distance. This indicates a linear relation between withstand voltage and flashover distance within this voltage range. It is reasonable to believe that the linearity will remain also up to 300 kV system voltage. For voltages ≥300 kV similar tests have been performed to establish wet switching impulse withstand values.

Based on the, by limit testing, established withstand voltages the rules for high altitude installations can be set. The standardized test voltages are altitude corrected according to IEC 61869-1 (Figure 2 above).

Instrument transformers in the ABB product family are of highly standardized designs and adoption for installation at high altitude can in most cases be made by selection of a standard design for a higher voltage rating. By this is assured that equipment for high altitude installation are of a well proven and type tested design and not a special design adopted for the dielectric requirements at high altitude.

In order to optimize the adoption of design for high altitude installation it is recommended that the standardized insulations levels and the installation altitude are stated in the technical specification for the instrument transformer. ABB will, based on that, make the needed design modifications and supply an optimized design.

ABB solution

In order to illustrate this, on page 5 and 6 we show some examples of how the high altitude installation are handled by ABB. The examples cover current transformers of the type IMB and capacitor voltage transformers of the type CPB for the system voltages 145, 245 and 550 kV for installations at altitudes up to 4000 m.

The internal high voltage insulation of the instrument transformers is not affected by the installation altitude. High voltage testing, at altitude <1000 m, of the external insulation with application of atmospheric corrections will in many cases result in overstressing of the internal insulation. This is acknowledged by IEC 60060-1, which in clause 4.3.6 states:

"….For those cases where the test voltage of the external insulation is higher than that of the internal insulation, the external insulation can only be correctly tested when the internal insulation is especially designed with increased strength. If not, the internal insulation should be tested with the rated value…"

The dielectric routine tests are therefore always performed with uncorrected standardized voltage levels applicable for the internal insulation. The electrical withstand of the external insulation is proven by type tests.

Example

For system voltage 145 kV and installation at an altitude of 2000 m will be selected an instrument transformer having an external flashover distance as for 170 kV system voltage, but the dielectric routine test will be performed at 275 kV as for 145 kV equipment.

Altitude correction for temperature rise
Minor modifications of ABB design take care of the problem

Altitude correction for temperature rise
For high altitude installations the thermal behavior of the oil immersed instrument transformer is affected by the reduction of air density. It means that the cooling ability of the air is reduced and temperature rise limits of internal parts of the instrument transformer, for installation at an altitude above 1000 m, must be reduced. The reduction factor for oil immersed instrument transformers is 0.4% per 100 m above 1000 m.

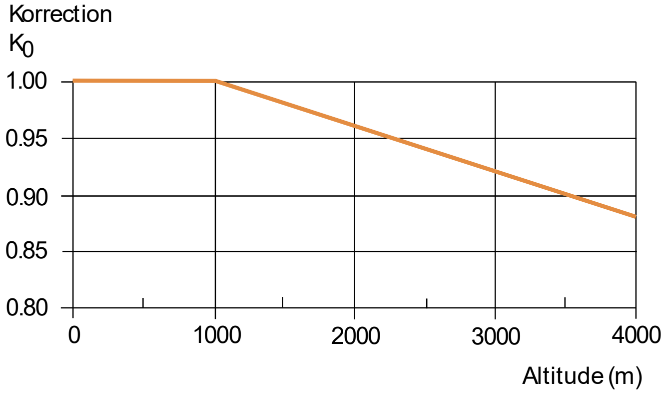


Figure 1. Altitude correction factor for the temperature rise

The altitude correction factor for the temperature rise is per IEC 61869-1 according to the formula:

$$K_0 = \frac{\Delta T_h}{\Delta T_{h0}}$$

- ΔT_h temperature rise at an altitude h >1000 m and
- ΔT_{h0} limits of temperature rise ΔT at altitudes ≤1000 m

Example
A current transformer shall be installed at an altitude of 3000 m. The temperature rise type test performed in a laboratory located <1000 m shows, for the primary winding, an average temperature rise of 61.2 K. The permitted winding average temperature rise is 65 K for oil immersed and hermetically sealed windings according to IEC 61869-1.

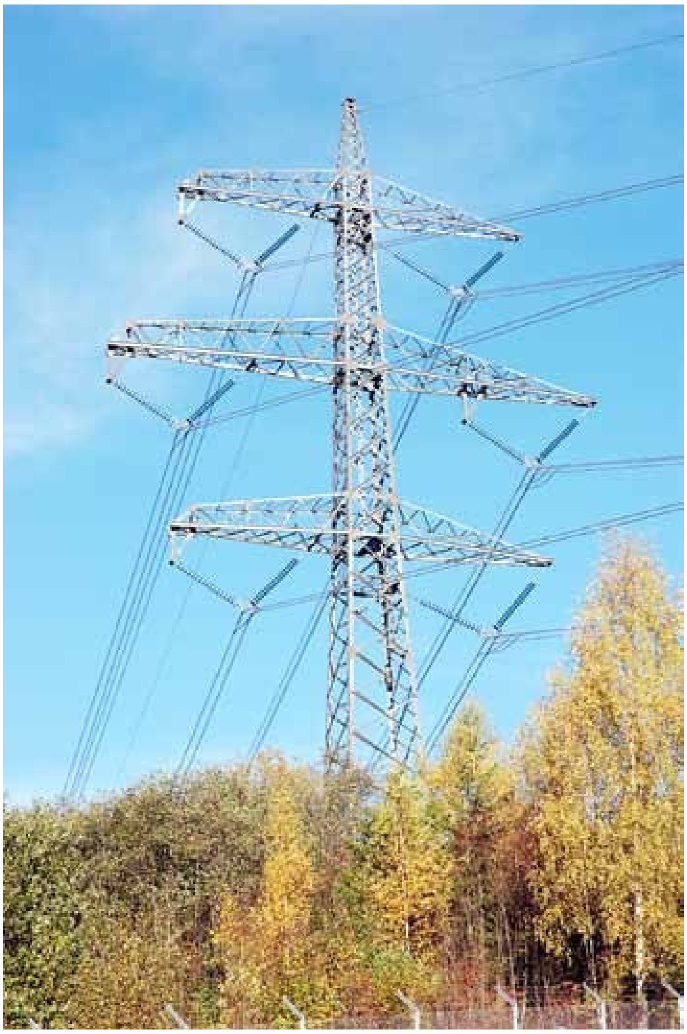
The altitude correction factor for 3000 m is 0.92, which gives a permitted temperature rise of 0.92 x 65 = 59.8 K.

This current transformer is not suitable for installation at 3000 m. The cooling ability must be improved.

For current transformers of the IMB design is the cooling ability improved by increasing the contact area in the top between internal oil and the external cooling air. This is achieved by replacing the expansion vessel in the top with a vessel having cooling fins on the outside and inside of the vessel wall.

Thermal calculation shows that the increased contact areas and cooling ability result in an average winding temperature rise of 35 K.

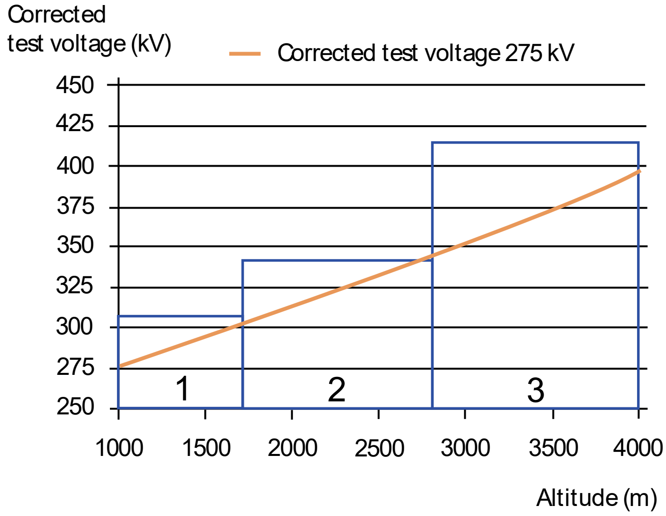
This minor modification makes the current transformer well suited for installation at an altitude of 3000 m.



Transmission line 420 kV

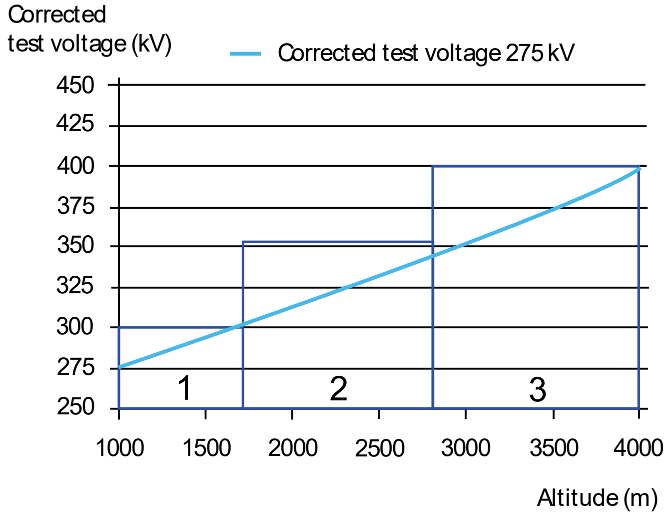
ABB standard designs for different altitudes

System voltage 145 kV
Current transformer IMB 145



1. Standard design IMB 145 up to altitude 1700 m
2. Standard design with flashover distance 1330 mm, for altitude 1700 - 2800 m
3. Standard design with flashover distance 1600 mm, for altitude 2800 - 4000 m.

System voltage 145 kV
Capacitor voltage transformer CPB 145



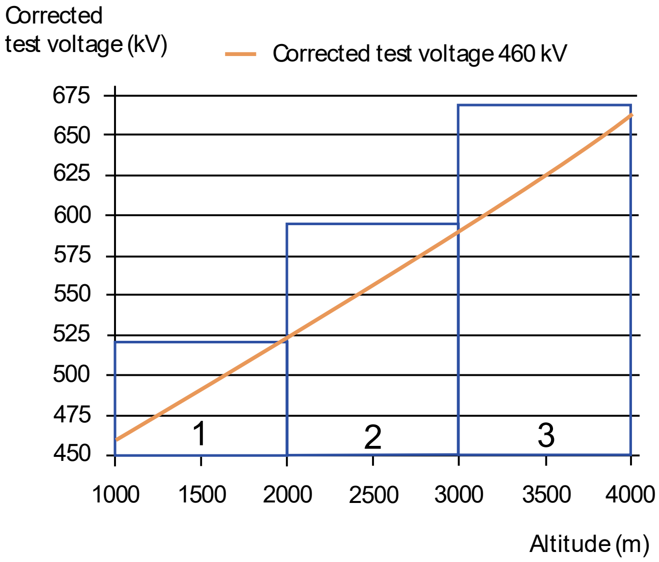
1. Standard design CPB 145 up to altitude 1700 m
2. Standard design with flashover distance 1400 mm, for altitude 1700 - 3000 m
3. Standard design with flashover distance 1610 mm, for altitude 3000 - 4000 m.

Current transformer IMB 145

Capacitor voltage transformer CPB 145

ABB standard designs for different altitudes

System voltage 245 kV
Current transformer IMB 245



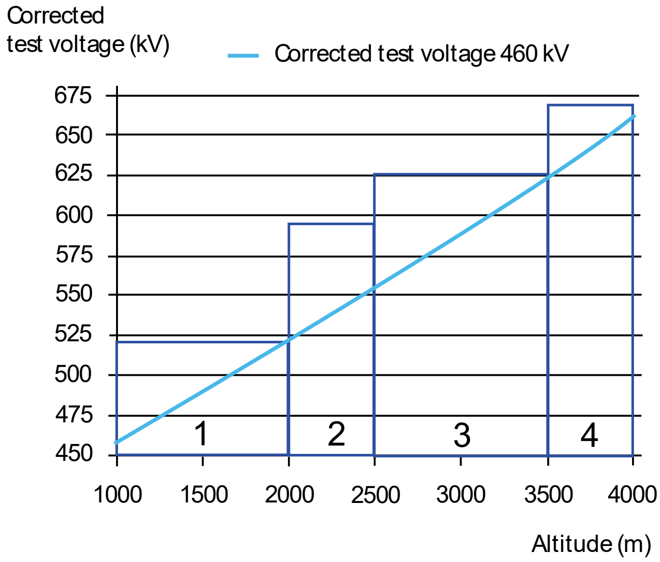
1. Standard design IMB 245 up to altitude 2000 m

2. Standard design with flashover distance 2265 mm, for altitude 2000 - 3000 m

3. Standard design with flashover distance 2715 mm, for altitude 3000 - 4000 m.

Current transformer IMB 245

System voltage 245 kV
Capacitor voltage transformer CPB 245



1. Standard design CPB 245 up to altitude 2000 m

2. Standard design with flashover distance 2100 mm, for altitude 2000 - 2500 m

3. Standard design with flashover distance 2380 mm, for altitude 2500 - 3500 m.

4. Standard design with flashover distance 2800 mm, for altitude 3500 - 4000 m.

Capacitor voltage transformer CPB 245