TechTopics Topic: Altitude Correction Factors

Medium Voltage Metal-Clad Switchgear and Outdoor High Voltage Circuit Breakers have ratings which are based on application under "usual service conditions" as defined in the applicable standards. Essentially, the "usual service conditions" defined in the ANSI standards encompass:

- Ambient temperature within the range of –30 °C to + 40 °C
- Altitude 1000 m (3300 ft) or below
- No significant solar radiation
- No significant adverse environmental considerations (e.g., corrosive fumes, dust, excessive humidity, and the like)

This issue of TechTopics discusses the adjustments required for applications above 1000 m in altitude. Historically, the altitude correction factors for high voltage circuit breakers were contained in ANSI/IEEE C37.04, while those for medium voltage Metal-Clad Switchgear were in ANSI/IEEE C37.20.2. At present, there is controversy in the IEEE Switchgear Committee regarding the appropriate altitude correction factors, with the result that the factors were removed from C37.04-1999, and a note was added to C37.20.2-1999 to indicate that the factors were under review. Accordingly, this discussion will recount the historic adjustment factors for medium voltage products.

Parenthetically, it should also be noted that low voltage power circuit breaker switchgear (i.e., ANSI/IEEE C37.20.1) equipment uses different altitude correction factors. Accordingly, the discussion in this issue of TechTopics does not apply to low voltage switchgear equipment.

In brief, altitude correction factors must be applied to the ratings of medium voltage metal-clad switchgear and outdoor high voltage circuit breakers as follows:

**Altitude Correction Factors - General**

| Rating | Adjustment |
|---|---|
| Maximum design voltage<br>Lightning Impulse withstand voltage (BIL)<br>Power frequency withstand voltage (hipot) | Adjust downward 1% per 100 m over 1000 m altitude |
| Continuous current | Adjust downward 1% per 500 m over 1000 m altitude |

For convenience, altitude correction factors for several altitudes are as follows:

**Altitude Correction Factors – Selected Altitudes**

| Characteristic | Altitude (m / ft) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1000<br>3280 | 1200<br>3940 | 1400<br>4600 | 1500<br>4920 | 1600<br>5250 | 1800<br>5900 | 2000<br>6560 | 2500<br>8200 | 3000<br>9840 | 3500<br>11500 | 4000<br>13125 |
| Voltage | 1.00 | .98 | .96 | .95 | .94 | .92 | .90 | .85 | .80 | .75 | .70 |
| Current | 1.00 | .996 | .992 | .990 | .988 | .984 | .980 | .970 | .960 | .950 | .940 |

For example, suppose we have an application of metal-clad switchgear with ratings as shown in column 2, applied at an altitude of 2000 meters. The application of the altitude correction factors would give the following capabilities at 2000 meters altitude:

| Rating | Rating for "usual service conditions" | ACF | Capability at 2000 m |
|---|---|---|---|
| Maximum design voltage | 15.0 kV | .90 | 13.5 kV |
| Lightning Impulse withstand voltage (BIL) | 95 kV | .90 | 85.5 kV |
| Power frequency withstand voltage | 36 kV | .90 | 32.4 kV |
| Continuous current | | | |
| • Main bus | 2000 A | .98 | 1960 A |
| • Main breaker | 2000 A | .98 | 1960 A |
| • Feeder breakers | 1200 A | .98 | 1176 A |

Recommendations:

- The maximum continuous service voltage (rated system voltage plus maximum sustained overvoltage) must not exceed the calculated voltage capability at the site altitude, 13.5kV in this example. For most systems, ANSI C84.1 indicates that the maximum system voltage limit is 106% of the rated system voltage. Therefore, for this example, the rated system voltage should not exceed 13.5 kV / 106% = 12.7 kV.
- For most applications, the adjustment to continuous current is insignificant. Equipment is seldom applied at the limits of its continuous current capability, and even if the load current rating matches the equipment rating, the ambient temperature at higher altitudes is often lower than the 40 °C ambient that is used for the basis of ANSI ratings. For this example, the 2% reduction in continuous current capability would be fully offset by a reduction in maximum ambient temperature from 40 °C to 37.3 °C.
- The adjustments in dielectric capabilities, particularly the BIL, are much more significant. Careful consideration must be given during the overall system design phase to insulation coordination studies, and surge arrestors should be considered for all circuits to protect the equipment from transient voltages in excess of its capabilities. This is of particular importance when one considers that higher altitude locations are often areas of higher than normal isokeraunic (thunderstorm) activity.

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