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Altitude correction factors

Medium-voltage metal-clad switchgear and outdoor high-voltage circuit breakers have ratings that are based on application under "usual service conditions," as defined in the applicable standards. Essentially, the "usual service conditions," defined in the ANSI/IEEE standards encompass:

- Ambient temperature within the range of –30 °C to +40 °C
- Altitude 1,000 m (3,300 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 1,000 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.

For a number of years, there has been 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 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 (e.g., 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, the historic altitude correction factors that must be applied to the ratings of medium-voltage metal-clad switchgear and outdoor high-voltage circuit breakers are as follows:

Altitude correction factors – general

Rating	Adjustment
Maximum design voltage Lightning impulse withstand voltage (BIL) Power-frequency withstand voltage (high-potential)	Adjust downward 1% per 100 m over 1,000 m altitude
Continuous current	Adjust downward 1% per 500 m over 1,000 m altitude

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

Altitude correction factors – selected altitudes

	Altitude (m/ft)										
Characteristic	1,000 3,280	1,200 3,940	1,400 4,600	1,500 4,920	1,600 5,250	1,800 5,900	2,000 6,560	2,500 8,200	3,000 9,840	3,500 11,500	4,000 13,125
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

Answers for infrastructure.

For example, suppose we have an application of metal-clad switchgear with ratings as shown in column 2, applied at an altitude of 2,000 meters. The application of the altitude correction factors would give the following capabilities at 2,000 meters altitude:

Rating	Rating for "usual service conditions"	ACF	Capability at 2,000 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	2,000 A	.98	1,960 A
■ Main circuit breaker	2,000 A	.98	1,960 A
■ Feeder circuit breakers	1,200 A	.98	1,176 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, 13.5 kV in this example. For most systems, ANSI C84.1 indicates that the maximum system voltage limit is 106 percent of the rated system voltage. Therefore, for this example, the rated system voltage should not exceed 13.5 kV/106 percent = 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/IEEE ratings. For this example, the two percent 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 arresters 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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