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TechTopics

TechTopics Topic: Expected Life of Electrical Equipment

How long should electrical equipment last? If engineers were surveyed regarding the life they expect from electrical equipment, the answers would probably range from a minimum of twenty years to a maximum tending towards infinity. It is not unheard of to find some ancient open-frame circuit breaker mounted on a two-inch thick slate panel still carrying current after 50 years.

The answer to this important question, however, is not as simple as quoting statistics or giving a set figure. The engineer only has to look around at the extreme range of operating conditions and environments, and the differing levels of past maintenance to realize the futility of trying to arrive at one numerical answer. If the electrical equipment is located in a high rise, modern office building, there is a good chance that general cleanliness prevails and temperatures are moderate. On the other hand, consider the same equipment in a paper mill or in a dust-filled environment, perhaps even in the tropics, and the life expectancy cannot be the same.

It should be obvious that a good maintenance schedule and regular inspections are required to keep electrical equipment in good working order, just as it would for a fine automobile. There is another factor working against longevity that deserves more attention than it usually gets. That factor is temperature. ANSI standards limit the total temperature for most bus conductors to 105°C. This results from the maximum design ambient of 40°C, plus the allowable temperature rise of 65°C. Thus, the maximum continuous temperature that most insulating materials will be exposed to is 105°C.

However, if the equipment were operated at its full temperature capability continuously 24 hours per day, 365 days per year, the life expectancy of the insulation would be pretty short. If this is so, why do we see examples of electrical equipment still in service 40 years or more after it was installed?

Consider the effect of elevated temperatures on insulation. The life of insulation follows a physical relationship based on temperature, expressed by the Arrhenius[‡] equation:

$$k = Ae^{-E_a/RT}$$

In this form, the equation is not terribly useful. However, if we take the natural logarithm and rearrange the terms, it becomes a generalized expression for a straight line:

$$\ln k = \ln A - (E_a/R) * (1/T)$$

Since A, E_a, and R are constants, this becomes a straight line with a negative slope of (E_a/R) plotted against the inverse of temperature (1/T).

The practical use of this expression is for estimating the life of electrical insulation, which would be the value “k” in the Arrhenius expression. There are a wide variety of insulating materials used in switchgear equipment, but a generalized rule-of-thumb is that the life of electrical insulation is reduced by half for each rise of 10°C in insulation temperature. The most commonly used indicator of electrical insulation life is dielectric capability, so the Arrhenius expression becomes an indicator of dielectric life.

This is how accelerated life testing is accomplished. An insulation material is placed in a controlled oven and held at elevated temperature to compress the time-to-failure. When failures do occur, the engineer works backwards to establish the MTBF at normal temperatures.

Let's look at a practical example of these concepts, and the implications for expected life of insulation in electrical equipment. Suppose we have a material which has an expected life of 20,000 hours at 125°C. What would its approximate life be at other temperatures?

Temperature (°C)	Life (hours)	Expected Life	
185	313	0.4	Months
175	625	0.9	Months
165	1,250	1.7	Months
155	2,500	3.5	Months
145	5,000	6.9	Months
135	10,000	13.9	Months
125	20,000	2.3	Years
115	40,000	4.6	Years
105	80,000	9.1	Years
95	160,000	18.3	Years
85	320,000	36.5	Years
75	640,000	73	Years

For this example, if the material is used in switchgear with 105°C maximum total temperature at rated continuous current, it would have an MTBF of 9.1 years. On the other hand, if the total temperature is reduced by 20°C, the life would increase to over 36 years.

The temperature of a bus bar, and therefore of the insulation material that supports and surrounds it, is a function of the ambient temperature around the bus bar, and the square of the loading. Thus, if 100% current yields 65°C temperature rise, 80% loading will produce 64% of 65°C, or 42°C temperature rise. This is a reduction of 23°C from the temperature at 100% loading, resulting in an increase of life expectancy from 9 years to more than 40 years.

This example illustrates the dominance of temperature as a determinate of insulation life, and explains why electrical equipment applied conservatively is still in use after 40 years of more. Ambient temperature is also significant, but of lesser import as its effect is not a square relationship. When we design switchgear equipment, our objective is that the equipment will have an insulation life upwards of 30 years when applied in a reasonably conservative manner in the usual service conditions defined in ANSI standards. Of course, the quality of maintenance and the installed environment will have a very significant effect.

Users can't change the laws of physics, but users do have some input for the conditions in which electrical products are applied. Ambient temperature, loading, maintenance, and environmental conditions are within the user's control. Together, these factors determine the answer to the question, 'How long will it last?"

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‡ Dr. Svante August Arrhenius was a Swedish scientist, professor of physics, and the founder of physical chemistry. In 1903, he received the Nobel Prize for Chemistry for his study of ionic theory.