

# Medium Voltage Transformers – Volume II

An Online Continuing Education Course for Engineers

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# Medium Voltage Transformers – Volume II

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## Introduction

Electrical transformers are a key component in an electric power system. Generating plants produce power at medium voltage levels (5-35 kV), which is then stepped up to higher voltages (230-765 kV) to transmit the power to communities. At this point, the voltage is stepped back down to medium voltages for delivery to homes and businesses. At that point, the medium voltage transformers again step the voltage down to levels suitable for residential, commercial, and industrial applications.



There are over 50 million medium voltage transformers in use in the United States, and approximately one million new transformers are added to the electric grid each year to either replace old transformers or to provide capacity for new loads. IEEE standards define a distribution transformer as any transformer rated 500 kVA and below. However, utilities tend to consider a distribution transformer as any transformer that reduces the voltage from the medium voltage levels to end-user levels. Medium voltages are voltages in the 5 kV to 35 kV range, and the end user voltages are typically 600 volts or less.

Transformers are rated based on the amount of power they can transform. The ratings are usually listed in kilovolt-amps or kVA. A typical distribution transformer is 7200/12470Y-120/240V, 15 kVA. This transformer is rated to transform a primary distribution voltage of 7,200 volts, phase-to-ground to 240 volts, with a center tap to provide two phases of 120 volts, up to a power capacity of 15 kVA.

Electrical transformers are available in a multitude of types, sizes, and ratings. A few examples are,

- Oil filled transformers,
- Dry-type transformers,
- Air-cooled transformers,
- Step-up and Step-down transformers,
- Single-phase and three-phase transformers, and
- Regulating transformers.

Regardless of the type, they all work on the same basic principle, which is an electric current creates a magnetic field in a coil of wire that can then induce a voltage in a second coil of wire. With a few exceptions, the incoming and outgoing electric circuits in a transformer are not electrically connected. They are only related by the magnetic field between the two coils of wire.

Modern distribution transformers are manufactured in accordance with many standards, most notably by the Institute of Electrical and Electronics Engineers (IEEE) and the International Electrotechnical Commission (IEC). IEEE Standard C57.12.00 “Standard General Requirements for Liquid-Immersed Distribution Power and Regulating Transformers” describes the functionality of medium voltage distribution transformers. Other standards address specific components of transformers, too.

This course is divided into two volumes. The first volume addresses the electrical characteristics of medium-voltage transformers, design characteristics, transformer types, and standards.

Volume II discusses practical applications of medium-voltage transformers, such as loading issues and energy losses, transformer components, and wiring connections used to produce different voltage configurations. It also covers other factors, such as how fault current generation and ferroresonance impact transformer operation.

The first chapter of this course discusses transformer loading issues. Chapter two explains how to calculate the cost of transformer losses. Chapter three delves into single-phase transformers, both pole-mounted and pad-mounted units. Chapter four describes the different types of three phase connections that are possible. The final chapter covers several ancillary issues related to medium voltage transformers.

# Chapter 1

## Loading

As mentioned in Volume I of this series, medium-voltage transformers are defined in IEEE Standard C57.91, which defines the transformer loading characteristics of mineral oil-filled overhead and pad-mounted distribution transformers. The standard is based on a 65C temperature rise above ambient. A transformer's rating is based on the effect of temperature on the insulation life and the ambient temperature at the transformer location.

## Cooling Factors

Transformer cooling, and hence, its temperature rise, is based on the ambient temperature, the altitude of the transformer installation, and the solar radiation heating of the transformer tank.

## Ambient Temperature effects

The standard assumes that the ambient temperature at rated load is at an average of 30C for 24 hours with the maximum temperature no greater than 10C above the average. If the temperature is significantly above or below 30C, the transformer rating will be affected. A rule of thumb is that a transformer rating can be increased or decreased based on ambient being less than or greater than 30C respectively. The following table has these rule-of-thumb factors for ambient temperatures other than 30C. See Table 1.

<b>Table 1</b>	
<b>Loading Impact of Ambient Temperature</b>	
<b>Condition</b>	<b>Factor</b>
Ambient > 30C	1.5%
Ambient < 30C	1.0%
Note: Adjust the rating for each degree from 30C.	

From this table, we see that a transformer should be derated 1.5% for each degree that the ambient temperature is above 30C and that the transformer rating can be increased 1.0% for each degree that the ambient temperature is below 30C.

**Example.** What is the impact on the rating of a 75 kVa transformer that is operating in a 50C ambient condition?

Since 50C is 20 degrees above the normal ambient, the transformer should be derated by,

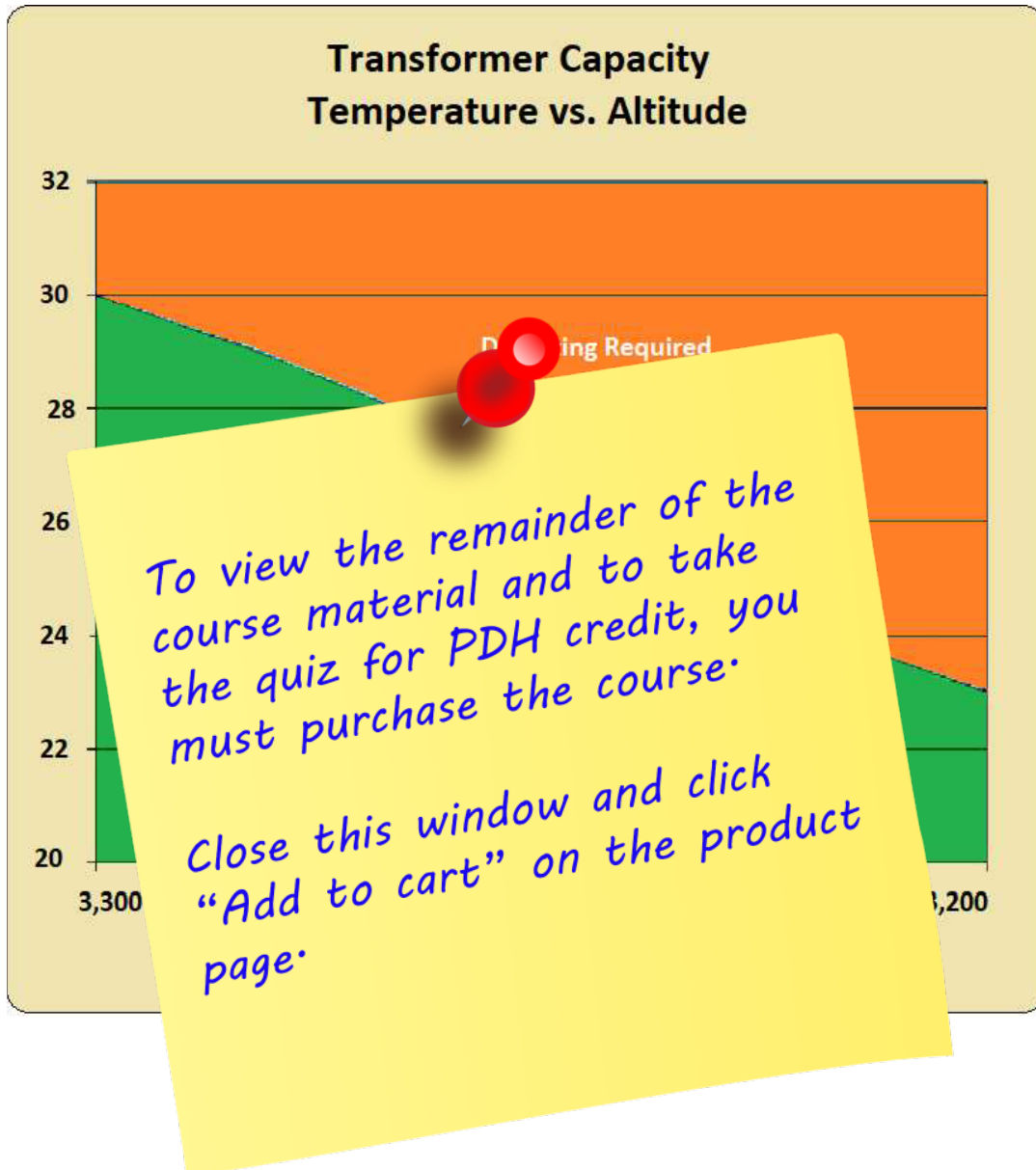
$$20 * 1.5 = 30\%.$$

Therefore, the transformer capacity at an elevated temperature of 50C is,

$$75 \text{ kVA} * (1 - 0.30) = 52.5 \text{ kVa}.$$

## Altitude Effects

Reduced air density at higher altitudes lessens the ability of transformers to dissipate heat. Transformers are designed to deliver rated kVA at elevations up to 3,300 feet (1,000 meters). Above 3,300 feet, the transformer may have to be de-rated depending on the ambient temperature. The following graph shows the effects of temperature versus altitude (Figure 1).



From this graph, a transformer can operate up to rated kVA at an altitude of 6,600 feet, provided the ambient temperature is 28C or less. Above 28C at 6,600 feet, the transformer needs to be de-rated.

To compensate for the effects of altitude (assuming a 30C ambient temperature), the transformer capacity must be reduced by 0.4% for each 10% feet of altitude above 3,300 feet.

$$\text{Derate} = \left( \frac{\text{Altitude}}{3,300} - 1 \right) * 0.04 * 100$$

**Example.** How much must a transformer be derated at 6,600 if the ambient temperature is 30C?

$$\text{Derate} = \left( \frac{6,600}{3,300} - 1 \right) * 0.04 * 100 = 4\%.$$