

## **1C.3.1—Voltage Balance**

**ENGINEERING**  
**Standards and Technical Support Department**

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## 1C.3.1—Voltage Balance

### 1 Scope

This document defines and presents PacifiCorp's guidelines for voltage balance.

### 2 General

Unbalanced voltages can cause various problems. Three-phase motors may run hotter, unless the motors are derated. In some cases, unbalanced voltages have caused malfunctions in variable speed drives, unless there is provision for better filtering of the dc output from the rectifier.

A major cause of unbalanced voltage is unbalanced load current. An example is unbalanced customer load causing unbalanced voltage to that same customer.

### 3 Definition of Voltage Unbalance

The definition of voltage unbalance is found in Appendix D of ANSI Std C84.1–1989, *Voltage Ratings for Electrical Power Systems and Equipment*. That standard was concerned with the effect on motors; therefore, phase-to-phase voltages were used in the example. Voltage unbalance of a polyphase system is defined as follows:

$$\% \text{ voltage unbalance} = 100 \times \frac{(\text{maximum deviation from average voltage})}{(\text{average voltage})}$$

Example:

With phase-to-phase voltages of 230, 232, and 225, the average is 229; the maximum deviation from average is 4; and the percent unbalance is  $(100 \times 4) / 229 = 1.75$  percent.

### 4 Voltage Unbalance Limits

Relatively small voltage unbalances are often achievable close to substations on circuits with well balanced loads; however, farther out on circuits it can be very expensive, and extremely difficult to achieve a high level of voltage balance.

User equipment, such as motors, can often be derated so that it will still operate despite relatively large voltage unbalances, but this can be very expensive, and in some cases the equipment will not operate properly. A reasonable middle ground, based on an attempt to reach the lowest total cost to the customer and to the utility, is included in the recommendations of ANSI Std. C84.1–1989. The ANSI recommendations are:

1. Electric supply systems should be designed and operated to limit the maximum voltage unbalance to three percent when measured at the electric utility revenue meter under no-load conditions.

2. If an electric supply system is operating near the upper or lower limits of the ANSI Std C84.1–1989 voltage ranges, each individual phase voltage should be within the listed limits. (These voltage ranges are listed in 1C.2.1, *Voltage Level and Range*, in this Handbook.)

It is important to recognize that operation under strict limits for voltage balance would require major system change, which cannot be economically justified from the standpoint of the customer or PacifiCorp. In other instances, unique or changing system conditions may make it impractical to remain within specific limits for all operating situations. However, PacifiCorp makes every reasonable effort to maintain voltage balance to meet the needs of typical customer equipment and the most efficient utilization of the distribution system.

## 5 Voltage Balance Measurements

Many three-phase loads are served from transformers with four-wire wye connected low-voltage windings, such as 208Y/120 volts, or 480Y/277 volts. Three phase-to-neutral voltage readings of 122.0, 118.0, and 118.0 volts have an average of 119.3 volts, a maximum deviation of 2.7 volts, and an apparent unbalance of 2.23%.

Motor windings are usually delta connected and are sensitive to the phase-to-phase voltages. In the case above, the three voltages could have phase angles of zero degrees, 122 degrees, and 238 degrees. The phase-to-phase voltages would be 209.9, 200.1 and 209.9 volts. This would give an average of 206.7 volts, a maximum deviation of 6.5 volts and an unbalance of 3.15 percent. This shows the need to measure the voltages from phase-to-phase.

## 6 Issuing Department

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