APPENDIX "C"

POLYPHASE VOLTAGE UNBALANCE

C1. Introduction

Studies on the subject of three-phase voltage unbalance indicate that:

(1) All utility-related costs required to reduce voltage unbalance and all manufacturing-related costs required to expand a motor's unbalanced voltage operating range are ultimately borne directly by the customer.

(2) Utilities' incremental improvement costs are maximum as the voltage unbalance approaches zero and decline as the range increases and

(3) Manufacturers incremental motor-related costs are minimum at zero voltage unbalance and increase rapidly as the range increases.

When these costs, which exclude motor-related energy losses are combined, curves can be developed that indicate the annual incremental cost to the customer for various selected percent voltage-unbalance limits. The optimal range of voltage unbalance occurs when the costs are minimum.

Field surveys and statistics indicate that:

(1) Each motor rating is associated with a unique optimal range of voltage unbalance

(2) These ranges vary from 0 - 2.5 percent to 0 - 4.0 percent voltage unbalance with the average at approximately 0 - 3.0 percent.

(3) Approximately 98 percent of the electric supply systems surveyed are within the 0 - 3.0 percent voltage-unbalance range, with 66 percent at 0 - 1.0 percent or less.

C2. Recommendation

Electric supply systems should be designed and operated to limit the maximum voltage unbalance to 3 percent when measured at the electric-utility revenue meter under no-load conditions. This recommendation should not be construed as expanding the voltage ranges.

C3. Definitions

Voltage unbalance of a polyphase system is expressed as a percentage value and calculated as follows:

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

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 (100x4) / 229=1.75 percent

C4. Derating for Unbalance

The rated load capability of polyphase equipment is normally reduced by voltage unbalance. A common example is the derating factor used in the application of polyphase induction motors.

C5. Protection from Severe Voltage Unbalance

User systems should be designed and operated to maintain a reasonably balanced load.

In severe cases of voltage unbalance, consideration should be given to equipment protection by applying unbalance limit controls.