There are many different definitions of unbalance (or imbalance – even the word itself has variations!) used in three-phase electric power systems. This application note discusses two of the most common definitions.

Summary

Of the many definitions of unbalance, the two most commonly used are (1) the American National Standards Institute (ANSI) C84.1 definition, and (2) the symmetrical components definition.

The good news is that both definitions produce the essentially the same readings for small unbalance readings, so typically there is no difference between these definitions for voltage unbalance.

For current unbalance, each definition has advantages and disadvantages.

Neither is more “correct” than the other; each simply has a set of applications for which it is preferable.

Definitions

**ANSI C84.1 unbalance**: the ratio of the maximum deviation of an RMS voltage (or current) from the average RMS voltage (or current) to the average RMS voltage (or current), expressed in percent, preferably using phase-to-phase voltage measurements (or phase current measurements).

**Symmetrical components unbalance**: the ratio of the magnitude of the fundamental negative-sequence voltage (or current) to the magnitude of the fundamental positive-sequence voltage (or current), expressed in percent.

**Precision unbalance measurements – when do they matter?**

Precise voltage unbalance measurements can be important, because measurement of voltage unbalance are often related to standards compliance. For example, the voltage unbalance either exceeds the 95% cumulative probability limits, or it doesn’t. But these unbalance limits are generally small, so they are not affected significantly by your choice of definitions.

Precise current unbalance measurements are usually less useful or important. The important question with
current unbalance is: what action are you going to take? Will you choose one action if the current unbalance is 30%, and a different action if it is 40%? Usually, there will be no difference in your choice of action. So precise current unbalance measurements – or choices about current unbalance definitions – are probably less important in most applications.

**Choice of definition does not affect voltage unbalance**

For voltage unbalance measurements, the choice of definition is not important because (a) the voltage unbalance tends to be small, and (b) the fundamental voltage phasors tend to be close to 120° apart, and (c) the voltage harmonics tend to be both small in amplitude relative to the fundamental, and balanced. All three of these factors mean that the ANSI definition and the symmetrical components definition produce almost exactly the same results. See the example below.

**Choice of definition does make a difference for current unbalance**

For current unbalance measurements, the choice of definition is more important, because (a) current unbalance tends to be an order of magnitude larger than voltage unbalance, and (b) the fundamental current phasors tend to vary in angle, and (c) the current harmonics tend to be at least an order of magnitude larger than the voltage harmonics. So the choice of definition is important for current unbalance: the two definitions can produce different results.

**Advantages and disadvantages of each definition for current unbalance**

The ANSI definition is based on the RMS current readings, so it includes the harmonic currents (advantage). However, it ignores the phase angle of the fundamental current vectors (disadvantage). The ANSI definition matches more closely with how 3-phase electronic loads respond to unbalance (advantage). This definition includes the zero-sequence currents (advantage in some cases). Because this definition is based on the difference between RMS current readings on each phase, the ANSI definition is more closely matched with the traditional, intuitive definition of current unbalance (advantage).

The symmetrical components definition is based on the fundamental current vectors, so it ignores any harmonic currents (disadvantage), and it ignores zero-sequence currents (sometimes an advantage, and sometimes a disadvantage, depending on the application). But this definition does take into account the phase angle of the fundamental current vectors, which can be important if the mixture of inductive and resistive loads is different on each phase (advantage), and it matches more closely with how transformers and motors respond to unbalance (advantage). The symmetrical components definition depends on fairly complicated mathematics, and is difficult to explain – it is not intuitive at all (disadvantage).

**Recommendations**

For voltage unbalance, use either definition – the readings will be the same.

For current unbalance:

- The ANSI C84.1 definition is preferred if a significant part of the load is electronic (variable frequency drives, phase-controlled heaters, etc.).
- The symmetrical components definition is preferred if almost all of the load is inductive or resistive (motors, directly-connect heaters, transformers, etc.).
An example that compares the two definitions

Consider a measurement where the phase-to-phase voltage phasors are $230 \angle 0^\circ$, $237 \angle -118^\circ$, and $240.6 \angle 119.6^\circ$ volts, respectively, with no harmonic content in the voltages.

The fundamental sequence components are $V_{pos} = 233.8 \angle 0.5^\circ$, and $V_{neg} = 6.2V \angle -159.7^\circ$. Unbalance with the symmetrical components definition is 2.6%.

The average RMS voltage is $235.9 V_{rms}$, and the maximum deviation is $5.9 V_{rms}$. So unbalance with the ANSI definition is 2.5% - essentially the same value.

Unbalance measurements in the PQube®

In firmware versions 1.2 and earlier, the PQube instrument (www.PowerStandards.com/PQube.htm) uses the ANSI definition of unbalance, because it is connected to electronic loads in many applications.

In firmware versions 1.3 and later (free field-installable upgrade), the PQube will allow expert users to choose the ANSI definition or the symmetrical components definition. The ANSI definition will be the default.