5.1 Per unit system

In the power systems analysis field of electrical engineering, a per-unit system is the expression of system quantities as fractions of a defined base unit quantity. Calculations are simplified because quantities expressed as per-unit do not change when they are referred from one side of a transformer to the other. This can be a pronounced advantage in power system analysis where large numbers of transformers may be encountered. Moreover, similar types of apparatus will have the impedances lying within a narrow numerical range when expressed as a per-unit fraction of the equipment rating, even if the unit size varies widely. Conversion of per-unit quantities to volts, ohms, or amperes requires a knowledge of the base that the per-unit quantities were referenced to. The per-unit system is used in power flow, short circuit evaluation, motor starting studies etc.

The main idea of a per unit system is to absorb large differences in absolute values into base relationships. Thus, representations of elements in the system with per unit values become more uniform.

A per-unit system provides units for power, voltage, current, impedance, and admittance. With the exception of impedance and admittance, any two units are independent and can be selected as base values; power and voltage are typically chosen. All quantities are specified as multiples of selected base values. For example, the base power might be the rated power of a transformer, or perhaps an arbitrarily selected power which makes power quantities in the system more convenient. The base voltage might be the nominal voltage of a bus. Different types of quantities are labeled with the same symbol (pu); it should be clear whether the quantity is a voltage, current, or other unit of measurement.

1. A common three-phase voltampere base is used throughout the system, where

$$S_{base,3\Phi} = 3S_{base,1\Phi} .$$

2. Once selected at a point in the network, the three-phase voltage base must vary according to the line-to-line transformer turns ratios.

Convenient formulas relating single-phase to three-phase bases are given below.

$$S_{base,1\Phi} = V_{base,line\text{ - }neutral} * I_{base}\ ,$$

$$S_{base,3\Phi} = 3S_{base1\Phi}$$

$$\text{Zbase} = \frac{V\ 2base}{S\ base\ 3\Phi}$$