Phase versus Polarity

Why voltages of opposite polarity shouldn't be said to be 'out of phase'

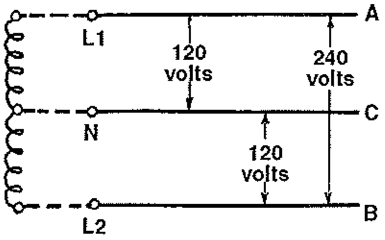

Figure 1. The widely used 120/240 volt three-wire single-phase residential electric service, erroneously thought of by many electricians as a "two-phase" supply.

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ONE OF THE MOST COMmon a-c power circuits, supplying most modern homes, is the 120/240 volt three-wire service. Such high-powered appliances as electric ranges or clothes dryers will be connected across the 240 volt portion (the two "hot" wires A and B in Figure 1) while lamps, TV's, and smaller appliances are connected between one of those wires and the "neutral," C.

Many electricians describe this as a *two-phase* system. They often justify that terminology by pointing out—correctly—that the voltage between conductors A and C is "negative" at the same time as the voltage B-C is "positive," so that those two voltages are to be considered as 180° out of phase with one another. The point is widely argued back and forth.

However, there can be no doubt about the true condition of such a circuit if we keep in mind just what *phase* means. In a polyphase circuit, each voltage is represented by a vector—a quantity having both magnitude and direction. A balanced three-phase version includes three vectors, each of the same magnitude, separated from one another by a 120° angle. For the two-phase situation, two voltage vectors are separated by a 90° angle.

That "phase angle" represents a difference in *time phase* between the voltages. Looking again at the more common three-phase situation, the 120° angle means that each of the three voltages reaches any given point on its sinusoidal variation exactly 1/3 of a cycle before or after each of the other two voltages. For a frequency of 60 Hz, that 1/3 cycle will be 1/180 of a second.

If the three-wire system of Figure 1 were a three-phase circuit, three voltages would be present, all of the same magnitude but separated in time phase by 1/3 cycle. Voltages A-C, C-B, and B-A would all be equal. Hence, the option of either 120 or 240 volts could not exist. For a two-phase system, voltages A-C and C-B would be equal but 90° apart in time phase; the voltage B-A would be the vector sum of the other two, or 1.41 times as great.

What Figure 1 represents is clearly a single-phase supply. Its source, a 240-volt transformer secondary, is connected to A and B, with a center tap connected to C (Figure 2a). During half of each cycle, the voltage A-C (which is half of the overall voltage A-B) alternates through exactly the same waveform variation as the equal voltage C-B. (See Figure 2b.) Those two voltages are in phase with each other.

As Figure 2b also shows, the relative *instantaneous polarity* of those two voltages is opposite to one another. But that has no effect on circuit performance or load behavior. If the two were 180° out of phase, as Figure 2c shows, they would cancel each other out, resulting in a voltage between A and B that would not be twice as great, but would be zero.

Thus, although the 120 volt legs of Figure 1 may be described as of opposite instantaneous polarity, they cannot be described as "out of phase." ■

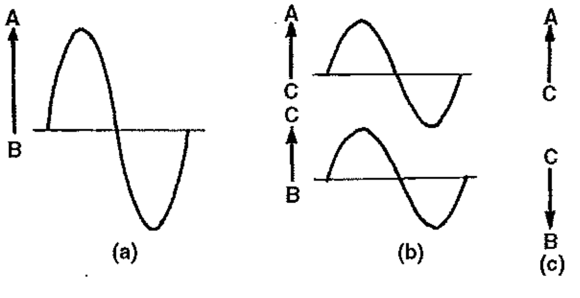

Figure 2. At (a), we see the voltage vector A-B, the transformer output, and its associated sinusoidal waveform. At (b), the two voltage vectors A-C and C-B, each half of the voltage A-B, and their waveforms—which will necessarily be of exactly the same time phase as the overall value A-B. If they were "out-of-phase"—opposed in vectorial direction, as shown at (c)—their resultant would be zero volts between A and B, an impossibility for the transformer connected as in Figure 1.