AC Circuits

Charles Pittman

April 23, 2013

Introduction

The study of electronics generally begins with exploring the function and operation of Direct Current (DC) circuits, with skills learned then translated for Alternating Current (AC) circuits. In that translation some students tend to focus more on applying the formulas in problem solving, losing sight of how they were derived. As a result, they may have trouble describing what AC is, how it functions, or how it's generated.

What is AC?

Because current flows in a single direction in DC circuits, the polarity of any terminal stays constant. As the name implies, direction of current flow in AC circuits alternates, and polarity at terminals with it. Figure 1 shows how these values change over time. One full alternation, or period, is marked by the section labeled T; the frequency of an AC waveform refers to the number of periods per second.

The horizontal axis in Figure 1 can be measured in time, degrees, or radians. One cycle of a sinusoidal wave is $360°$ or 2π radians. This figure also illustrates phase angle, either as the time delay between two waveforms or as the angle between them.

This time difference is also what is being referred to when a waveform is described as either "leading" or "lagging" another. With respect to a reference, a leading waveform is one that is further along in its cycle.

How is AC Generated?

Figure 2 shows a simple model of a three-phase alternator, consisting of a magnetic rotor and stator with three separate sets of coil windings mounted $120°$ from each other. In accordance with Faraday's law of induction, an electromotive force (EMF) is created in the conductors as the magnetic field rotates with the shaft, with each set of windings as a separate phase.

Not surprisingly, most values used in solving AC circuits describe the characteristics of the alternator. The period previously mentioned is one revolution of the rotor, so the frequency of the AC waveform produced is the number of revolutions per second.

What is Complex Power?

Impedance, the opposition of current in a circuit, is extended in AC. The fields in capacitors and inductors continue to grow in DC circuits until large enough to stop current and voltage, respectively. They function similarly in AC circuits, but discharge each time current changes direction.

The sum of capacitance and inductance, referred to as reactance, describes the energy stored in the circuit each cycle. A purely reactive impedence causes voltage and current to shift 90° out of phase, causing the current to return after only half a cycle. Though there is no net flow through the circuit, energy is still consumed because of the movement.

The power spent working against desired flow is termed reactive power and plotted on the imaginary axis in Figure 3. The sum of the real power transferred and reactive power wasted, complex power, is what actually reaches the load.

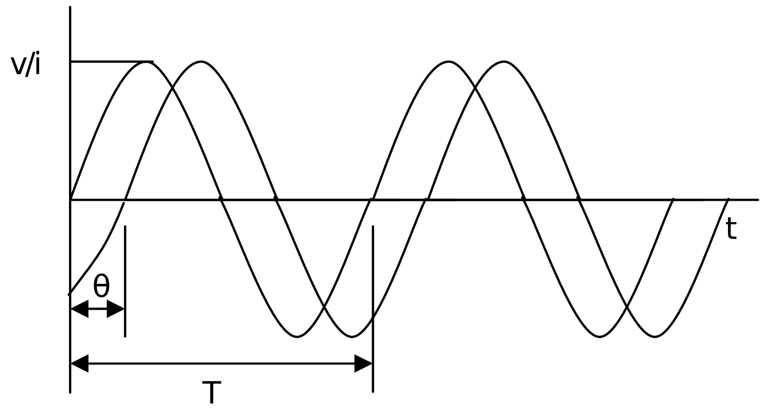

Figure 1: Two Sinusoidal Waves With Phase Difference

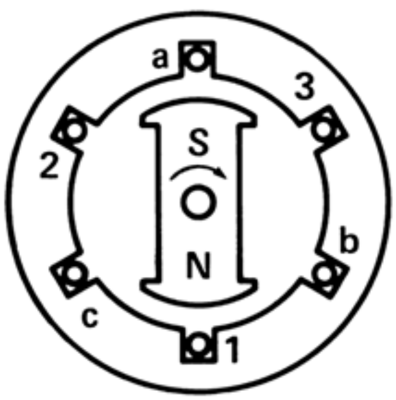

Figure 2: Simple Diagram of a Three-Phase Alternator

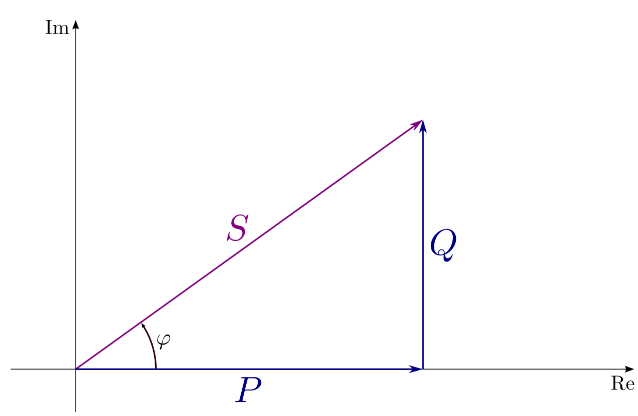

Figure 3: Complex Power Triangle