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 exactly what AC is and how it works.

What is AC?

Recall that current flows only one way in DC circuits. Since the current is moving in one direction the entire time the polarity of any terminal remains constant. As the name implies, current flows in alternating directions in AC circuits. The current changes direction, so polarity between terminals must change, thus voltage also alternates.

When plotted against time, an AC current (or voltage) produces a sinusoidal wave as shown in Figure 1 with one cycle (period) labeled as T. The period is used in defining another important value of the waveform, frequency, determined to be the number of periods per second.

Note that the horizontal axis can be divided into angles using the fact that a period in a sinusoidal wave is equal to 2π radians (or 360°). As the waves are periodic, when they fall out of phase, the difference occurs through the whole wave. This constant phase shift is labeled θ in Figure 1. By relating this shift of phase to the angle divisions along the axis, a phase angle is determined.

When referring to waveforms out of phase, it is common to determine one as "leading" or "lagging". With respect to a reference, a leading waveform is one that is further along in

its cycle. By convention, voltage is used as the reference in AC circuits.

How is AC Generated?

A simple model of a three-phase alternator is shown in Figure 2. It consists of a magnetic rotor, and spaced evenly around the stator are three separate sets of coil windings. As the rotor spins, an electromotive force (EMF) is produced, in accordance with Faraday's Law, that changes polarity as each magnetic pole passes over the windings.

Studying this motion, each value previously mentioned can be related, given a single rotation is one full period. If one revolution is a period, then the number of revolutions in a certain amount of time must be the frequency. Note that since the windings are evenly spaced, there is an angle of 120° between each, which is why each phase in a three-phase source is said to be offset by 120°.

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 impedance 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.
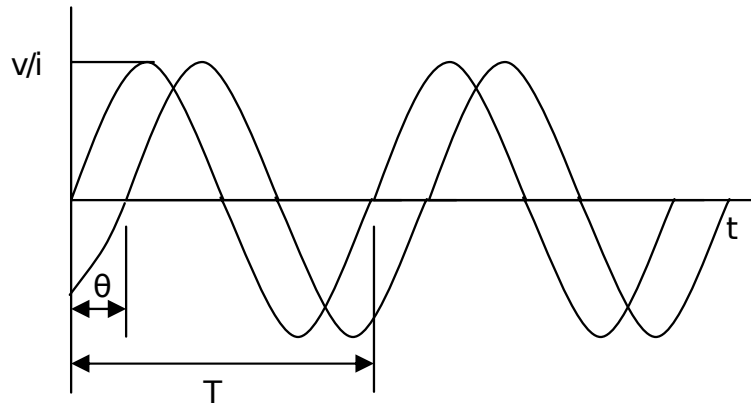
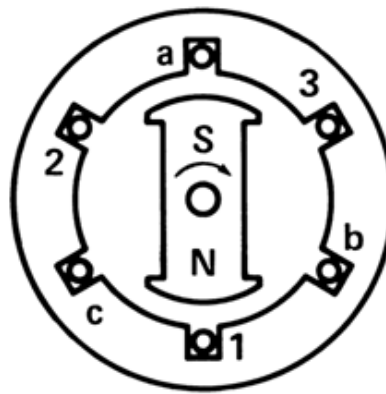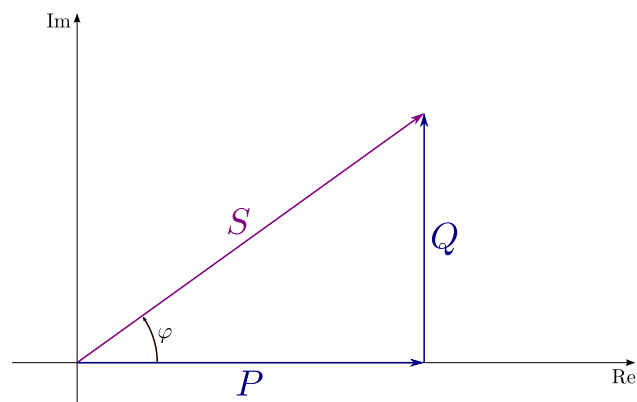Figure 1: Two Sinusoidal Waves With Phase Difference

Figure 2: Simple Diagram of a Three-Phase Alternator

Figure 3: Complex Power Triangle