Information Sheet # 118

Generator 101 (Part 2) Generator Single and Three Phase Formulas

Your Reliable Guide for Power Solutions

1.0 Introduction:

Power Generation is a multi-disciplined subject. A generator system is a sum of numerous parts requiring knowledge of many subjects including, but not limited to, electrical generation, engine mechanics, digital control, power distribution, principals of electricity, and switchgear control. This is Part 2 of a series addressing some electrical basics and terminology used in the generator system industry either as a buyer, specifier, user, technician, or sales person. While these sheets will not qualify you as a mechanical or electrical engineer (who if consulted will provide more in-depth explanation) they provide a general overview for a 101 comprehension of the subject.

This information sheet discusses the basics of; electrical generation, the difference between single and three-phase, when to apply and key formulas.

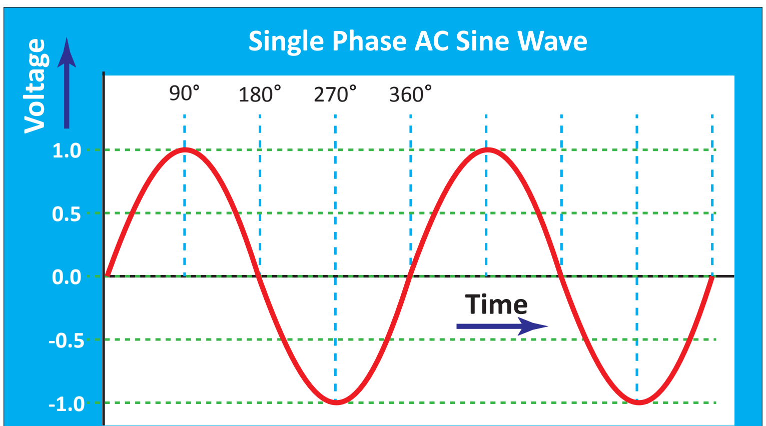

Figure-2 Positive voltage peaks at 90° and negative at 270°

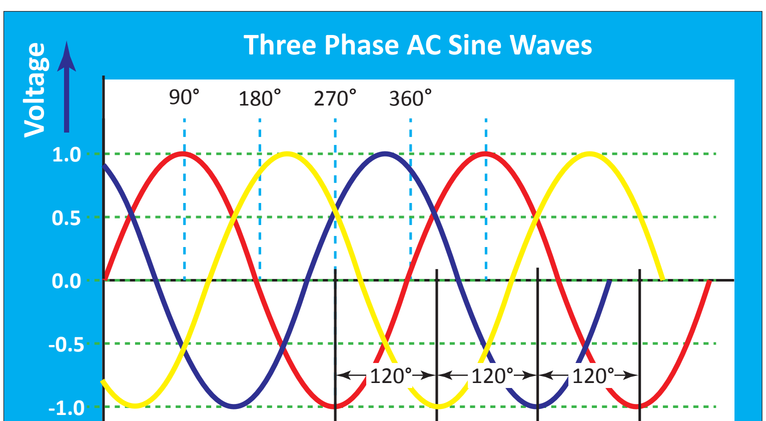

Figure-3 Sine Waves Peak 120° Apart

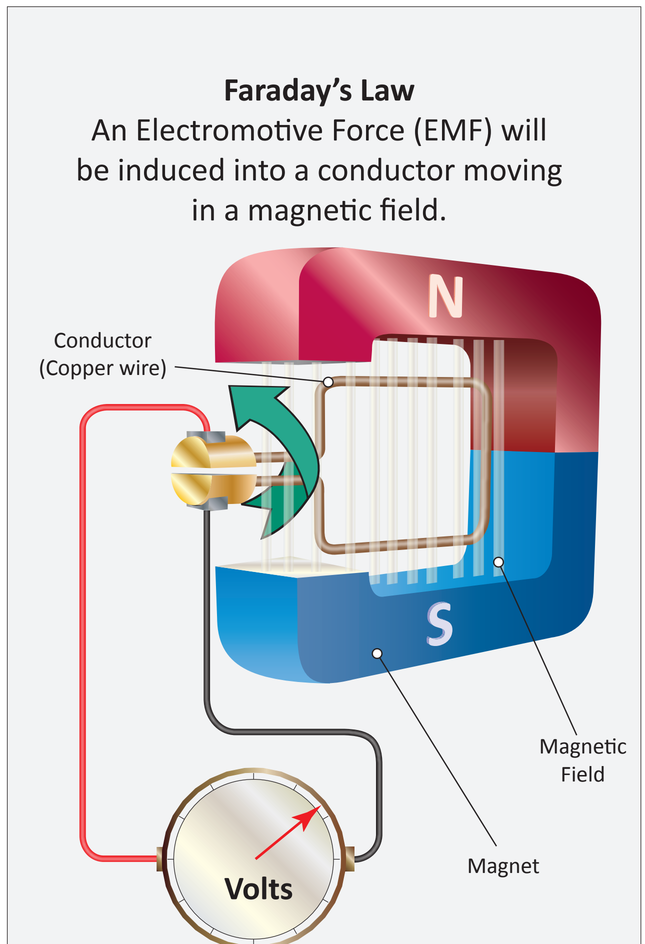

Figure-1

To fulfill our commitment to be the leading supplier in the power generation industry, the RP Power teams ensures they are always up-to-date with the current power industry standards as well as industry trends. As a service, our **Information Sheets** are circulated on a regular basis to existing and potential power customers to maintain their awareness of changes and developments in standards, codes and technology within the power industry.

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1.0 What Does Generator Phase Mean:

In electrical generator terminology, a phase refers to a positive and negative alternating current (AC) electrical power generated when wires complete a complete circle of rotation within a magnetic field. This follows Faradays law of generation that states, when a wire is rotated in a magnetic field an electromotive force (EMF) is induced into the wire, in AC power this is represented as a sine wave as illustrated in Figure-1.

1.1 Cycles – Cycles refer to the complete phases of rotation (360 degrees) the wires rotate in the magnetic field in one second. In North American, and most of Latin American, we adopt a system of 60-cycles per second. In electrical terminology a cycle is referred to as a Hertz (Hz), hence 60 Hz. The term frequency is also used and refers to the number of cycles per second.

1.2 60Hz Versus 50Hz – Other parts of the world, particularly Europe, have adopted a 50-Hz utility system. The more cycles per second the smoother the wave form.

1.3 Synchronous Speed, Frequency and Number of Poles – The wire coils (in which EMF is induced) rotating in the magnetic field are referred to as poles, see Figure-4. The quantity of poles is contingent on generator speed to provide the required frequency (cycles or Hz per second). Utility power in North America is supplied at 60Hz. The formula below is used to determine the required poles at a given generator speed. Most generator systems in North American are 4-pole running at 1800 rpm. However, many smaller generator sets are 2-pole running at 3600 rpm. Some (Oil and Gas Industry) prime power larger generator sets run at 1200 rpm 4-pole

Figure-4	Pole Formula	Formula Key	Examples	
	$P = \frac{120 \times Hz}{rpm}$	P = Number of Poles	$P = \frac{120 \times 60}{1800}$	P = 4
		Hz = Cycles per Second (Frequency)	$P = \frac{120 \times 60}{3600}$	P = 2
		rpm = Revolutions per Minute		

2.0 What is the Difference Between Single Phase and Three-Phase:

Phase refers to the distribution of the load across the windings within the generator and the number of wires used to distribute the power. AC power is generated as a sinusoidal (sine) wave (see *Figure-2*) where the positive power peaks at 90º and the negative power at 270º.

2.1 Single Phase (1P) – 1P power is a two-wire AC power system. Typically, there is one power wire (the phase wire) and one neutral wire, with current flowing between the power wire (through the load) and the neutral wire. The sine wave peaks at positive 90º and negative 270º as shown in *Figure-2*.

The advantages of 1P for residences and businesses is it is the simplest, most cost effective, less complex way of supplying power to loads under 10kW. However, for commercial and industrial applications that have much larger loads than 10kW it is an inefficient way to generate electrical power requiring heavier gauge copper wire, and less of a constant power supplied to the load with the power every 180º going to zero.

2.2 Three Phase (3P) – 3P power is a four-wire AC power system. Typically, there are three power wires (the phase wires) and one neutral wire, with current flowing between the power wire (through the load) and the neutral wire. Now there are three sine wave peaks at positive 90º and negative 270º as shown in *Figure-3*. In a 3P power system each power phase is spaced 120º apart, *Figure-3*. Most applications with total loads above 60kW and with many individual loads more than 10kW use 3P.

The advantages of 3P over 1p for larger power consumers, such as commercial and industrial businesses, is the power is more efficient, the power is more constant, never going to zero, requires less wire, and larger 3P motors are easier to start.

3.0 Single Phase Formula:

AC power is usually given as kilowatts (kW) or kilovolt amps (kVA), with the difference being the Power Factor (PF). Supplied PF is usually 1 (unity) in 1P systems, the kW and kVA are the same. With only two wires, one phase wire and the neutral, the formula to calculate power and current in a 60Hz systems is more straight forward as indicated in *Figure-5*.

Figure-5	1P Formula	Formula Key	kW to kVA Ratio
	$kVA = \frac{I \times V}{PF \times 1000}$	V = Volts (Phase Volts)	$kW = kVA \times PF$
		I = Amperes (Amp)	
		kVA = Kilo Volt Ampere	$kVA = \frac{kW}{PF}$
	$I = \frac{kVA \times PF \times 1000}{V}$	kW = Watts x 1000 (Power)	
		PF = Power Factor (1P Usually 1(unity))	

4.0 Three Phase Formula:

As for 1P, AC power is given in kWs and kVA. In a 3P system the PF is 0.8. In calculating 3P power the PF has to be accounted for. As a 3P system has 4 wires, 3 phase wires and one neutral the formula to determine the power developed in a 3P also has to take account of all the phases, hence the introduction of root three √3 as indicated in *Figure-6*.

Figure-6	3P Formula	Formula Key	Example 3P Calculation
	$kVA = \frac{I \times V \times \sqrt{3}}{PF \times 1000}$	V = Volts (Phase Volts)	120/208 V 3P; I=100
		I = Amperes (Amp)	
		kVA = Kilo Volt Ampere	$kVA = \frac{100 \times 208 \times 1.732}{0.8 \times 1000} = 45$
	$I = \frac{kVA \times PF \times 1000}{V \times \sqrt{3}}$	kW = Watts x 1000 (Power)	
		PF = Power Factor (3P Usually 0.8)	
		√3 = 1.732	kW = 45kVA x 0.8PF = 36