Information Sheet # 117

Generator 101 (Part 1) Ohm's Law, Electrical Voltage, and Conductivity

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 series of information sheets addresses some electrical basics and terminology that are regularly used by individuals involved in power generation.

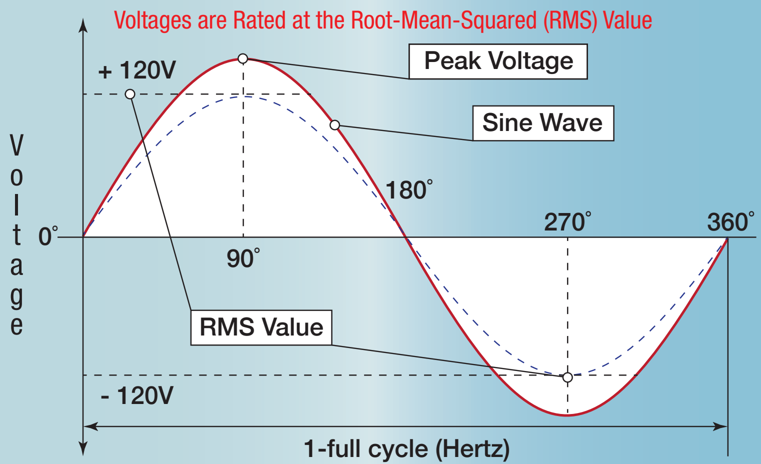
This information sheet series discusses the basics of electricity, including; Ohm's law, electrical voltage and conductivity as regards the best material for conducting electrical current and insulating from electrical current.

Ohm's Law Formulae Chart-1

Value to Calculate	Formula
Amperage (I)	I = V / R
Volts (V)	V = I x R
Resistance (R {Ohms Ω})	R = V / I
Power (W {Watts})	W = I x V
Amperage (I)	I = W / V
Volts (V)	V = I / W
kW	kW = W x 1000
Key to symbols of electricity	I = Amps; V = Volts; R= Ohms; W = Watts

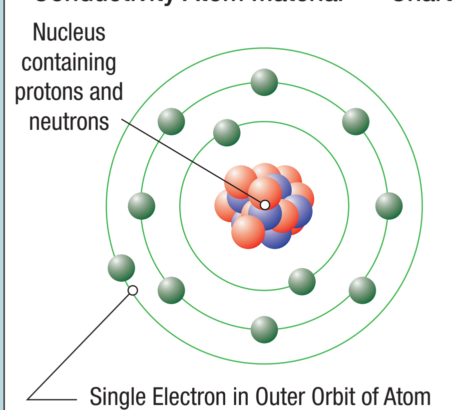
AC Voltage Sine Wave 120V Single Phase Chart-2

Voltages are Rated at the Root-Mean-Squared (RMS) Value

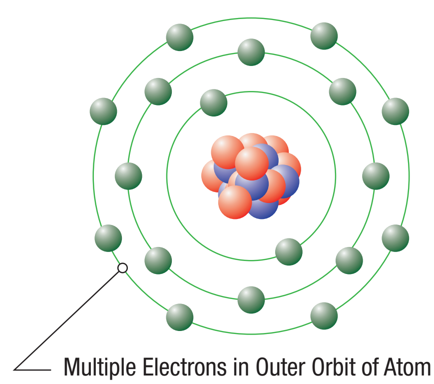


Conductivity & Insulation Chart-3

Conductivity Atom Material Chart-3A



Insulator Atom Material Chart-3B



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2.0 Ohm's Law:

Ohm's law, named after Georg Ohm who defined the law, links the three elements of electrical power voltage, resistance and current. Ohm came up with a formula to calculate the power generated when a current flow between two points, resistance, and the given voltage to generate current flow through a certain resistance. Ohm's law is the basic law for determining power generated. (Continued Over)

2.1 Defining the Relationships – Ohm determined that at a given voltage when the resistance increased the current flow between 2 points decreased, and the reverse when resistance decreased the current increased. This is a very important relationship to determine the power required at a given voltage across a conductor (resistance) between 2 points.

2.2 Ohm's Formula – Refer to ***Chart-1*** to see Ohm's formula expressed in different ways. However, the basic principal he defined was Amps (I) equals Voltage (V) divided by Resistance (R). The unit of resistance, Ohm is named after Ohm. The other key formula was the relationship between Amps (I) and Volts (V), where Amps times Volts defines the Power (W).

2.3 Power Definitions – Power generation is usually expressed in Kilowatt kW, which is 1000 Watts.

3.0 Electrical Voltages:

Power generation in North America has a wide range of voltages, this sheet covers the principal voltage and when used. There are two types of voltage. Direct Current (DC) and Alternating Current (AC). Early generator systems employed some DC but nearly all commercial, industrial and residential systems have utility power input requirements for AC power.

Residential power is single phase 120/240 volts AC. Larger commercial and industrial facilities will have up to 480 volts AC three-phase voltage inputs to power equipment with larger load demands.

3.1 What Is AC Voltage – Alternating Current (AC) is an electric current which periodically reverses in direction, as opposed to Direct Current (DC) that flows in one direction. The usual waveform of an AC current is a sine wave, refer to ***Chart-2***. The positive half period will correspond to the negative period through one complete cycle.

AC power is generated by a device called an alternator. In a brushless alternator (most commonly used in power generation as it eliminates brushes as power is produced in the static stator part) wires are crossed by a rotating magnetic field (the rotor), which induces a current in the stator wires. The rotation of the rotor is derived in power generation usually by a connected engine powered by diesel or other gaseous fuels.

3.2 Why AC for Power Generation – Residential and commercial outlets are almost always AC. It is easier to transport utility power from power stations over long distance. AC transmission lines (over 110,000V), lose less energy. Higher voltages mean lower currents, and lower currents mean less heat generated in the power line due to resistance. AC can be converted to and from high voltages easily using transformers.

AC is also used to power electric motors found in residential, industrial, and commercial applications. Also, using transformers, AC can be more easily converted into higher voltages than DC.

3.3 AC Voltage Sine Wave – An AC current has a sine wave form, with the voltage at the start of cycle 0 degrees going from rising to peak voltage at the top of the sine wave at 90 degrees, refer to ***Chart-2***. The voltage then falls as it follows the wave form to zero at 180 degrees. The sine wave, then goes negative reaching peak negative at 270 degrees before rising back to zero at 360 degrees, a full cycle. The generated power rating is not given as the peak voltage, but the Root-Mean-Squared, or average value, (RMS). The RMS value is approximately the peak value times 0.7.

4.0 AC Cycles:

In North America and most of Latin American you will notice the power supply is given as 60-cycles, and in modern power generation expressed as 60 Hertz (Hz). This basically means in an AC power system the alternating current goes through 60-cycles in one second. In other regions of the world, such as Europe, they have adopted a 50 Hertz (Hz) system, where the current, or sine wave, goes through 50-cycles in one second, refer to ***Chart-2***.

5.0 Conductors and Insulators:

When discussing conductivity and insulation, we have to consider the basics of what electricity is. Electricity is derived from electrons. Electrons are the particles within an atom orbiting the nucleus, refer to ***Chart-3***. Different materials have various combinations of electrons orbiting the nucleus. These combinations dictate whether a material is going to be more suitable as a conductor or an insulator.

5.1 Conductive Material – Conductive material, such as copper the principal wiring material used to conduct electricity, have a single electron or very few electrons orbiting the nucleus in the outer orbit, refer to ***Chart-3A***. As such these individual or few electrons are in a position to be readily moved from one atom to another, with an increased ability to sustain the movement of electrons. Gold is another material with good conductivity, but it is too expensive to use for regular wiring. However, in small electronic components gold contacts are used.

5.2 Non-Conductive Insulator Material – Insulator material, such as the clay-like material used on overhead distribution systems and the plastic insulating copper wires, have between 7 and 8 electrons orbiting in the outer ring of electrons circulating the nucleus, refer to ***Chart-3B***. When the outer ring includes more electrons, they limit the ability of any electron to move from one atom to another. In fact, they greatly resist the movement of electrons and the flow of electricity.

6.0 Electric Current:

Electric current is the movement of electrons across the atoms in a conductor, such as copper wire. This movement occurs when there is a potential difference (which is termed voltage) between the ends of a conductor, in most cases a copper wire connected to terminals.

As opposed to DC current that flows in one direction, AC current flows in both directions along a sine wave, refer to ***Chart-2.*** 120V AC, 60 Hz residential power is a typical AC current. There are 2 changes in polarity and 2 changes in current direction per cycle. The current in a 120V AC 60Hz electrical system changes direction 120 times per second.

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