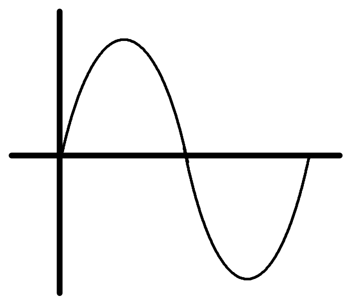
11. Glossary

11.1. Alternating Current – (Symbol AC): A current which periodically reverses in direction and changes its magnitude as it flows through a conductor or electrical circuit.

The magnitude of an alternating current rises from zero to maximum value in one direction, returns to zero, and then follows the same variation in the opposite direction. One complete alternation is one cycle or 360 electrical degrees. In the case of 60–cycle alternating current the cycle is completed 60 times per second.

Alternating current is far more widely used than direct current because it can be easily transformed from one voltage to another for transmission and use, and electricity is always generated in revolving machines as alternating current. A DC generator is basically an AC generator with the addition of a device called a commutator which changes AC to DC.



AC Wave

11.2. Alternator: A term frequently used for AC generator. ”AC generator” is preferred.

11.3. Ambient Temperature: The temperature of the surrounding air in which the equipment operates. This may be expressed in degrees Celsius or Fahrenheit. Normally, ambient temperature is expressed in degrees Celsius when referring to electrical equipment. Degrees Fahrenheit is more frequently used for engines and mechanical equipment.

11.4. Ammeter: This device measures current. Current measuring instruments must be corrected in series with a circuit and never in parallel with it. AC ammeters are often used with current transformers to reduce meter current. Typical transformer ratios are 100:5 and 500:5.

11.5. Amortisseur Winding: The revolving field structures of synchronous machines are provided with poles with faces slotted parallel to the shaft. Conducting bars are built into these slots, and the ends of the bars are short circuited to form a structure similar to the squirrel–cage winding of an induction motor. These windings dampen out the tendency of the generator to ”hunt” with load changes. They are required for all revolving field generators which are driven by internal combustion engines and which may be required to operate in parallel and/or single–phase.

11.6. Ampere – (Symbol I, A, i, a): A unit of measurement of the rate of flow of electricity. One ampere of current flows when a pressure of one volt is applied across an impedance of one ohm.

11.7. Apparent Power – (Symbol kVA, VA): When the current and voltage are not in phase, i.e., voltage and current do not reach corresponding values at the same instant, the resultant product of voltage and current is apparent power instead of actual power. Apparent power is measured in volt–amperes or kilo–volt–amperes. Actual power (kW) is the product of kVA and the power factor.

11.8. Armature Reaction: We know that if current flows through a coil surrounding an iron core, a magnet is formed. This is true of the stator as well as of the rotor. Current flowing through the stator coils will result in magnetic poles, in general, opposite in position and direction to the poles of the rotor. This characteristic of the stator, tending to oppose and to force down flux developed by the rotor, is known as armature reaction.

11.9. Automatic Synchronizer: This device, in its simplest form, is a magnetic–type control relay which will automatically close the generator switch when the conditions for paralleling are satisfied.

11.10. Automatic Transfer Switch: This switch is a double–throw , electrically operated switch which will, on a given signal, open one set of contacts and throw over to the second set of contacts. As normally used in hospitals, television and radio stations, and other applications where automatic emergency power is used, the switch automatically transfers a load from a normal source of electrical power to an emergency source on failure of the normal. The load is automatically returned to the normal source when that source is restored to proper operating condition. Relays for delayed operation, engine starting, manual reset, and similar features are available. As normally used, the switch is electrically operated, mechanically held, and has a positive interlock to prevent the two sets of contacts being engaged at the same time.

11.11. American Wire Gauge – (Symbol AWG): Wires are manufactured in sizes numbered according to a table, known as the American Wire Gauge. (This gauge was formerly know as Brown & Sharp, abbreviated B&S). As the wire diameters become smaller, the gauge numbers become larger. The ratio of the diameter corresponding to a given gauge number to the diameter corresponding to the next higher gauge number is a constant 1.123. The cross sectional area varies as the square of the diameter. The cross sectional area is approximately halved or doubled every three gauge numbers. The cross sectional area is increased or decreased 10 times for every 10 gauge numbers. Using No. 10 wire as a base (approximate diameter 100 mils, approximate cross sectional area 10,400 circular mils and 1 ohm per 1000 feet), it is possible to quickly estimate cross sectional area and wire size without referring directly to a wire table.

11.12. Brake Mean Effective Pressure (BMEP): Is the theoretical average pressure on the piston of an engine during the power stroke when the engine is producing a given number of horsepower. It is usually expressed in pounds per square inch. *For two–cycle engines, divide result by 2.

$$^{*}\text{BMEP} = \frac{792{,}000}{\text{Displacement (cu. in.)}} \times \frac{\text{Horsepower}}{\text{RPM}}$$

The value is strictly a calculation and cannot be measured, since the actual cylinder pressure is constantly changing. The mean or average pressure is used to compare engines on the assumption that the lower the BMEP, the greater the expected engine life and reliability. In practice, it is not a reliable indicator of engine performance for several reasons.

The formula favors older design engines with relatively low power output per cubic inch of displacement in comparison to more modern designs. Modern engines do operate with higher average cylinder pressures, but bearings and other engine parts are designed to withstand these pressures, but bearings and other engine parts are designed to withstand these pressures and still provide equal or greater life and reliability than their predecessors. The formula also implies greater reliability when the same engine produces the same power at a higher speed. Other things being equal, it is doubtful that a 60 Hz. generator set operating at 1800 is more reliable than a comparable 50 Hz generator set operating at 1500 rpm. Likewise, it is highly unlikely that any generator set operating at 3600 rpm will be more reliable than one operating at 1800 rpm even if the latter engine has a significantly higher BMEP. The BMEP for any given generator set will vary with the rating which changes depending on fuel, attitude, and temperature. The BMEP is also affected by generator efficiency which varies with voltage and load.

11.13. Broad Range: Generators having a range within which the output voltage can be adjusted are said to be ”broad range” machines. For example a generator rated 416–480 volt can be adjusted to put out anywhere between 416–volts and 480–volts.

11.14. Capacitance (Symbol C): If voltage is applied to two conductors separated by an insulator, the insulator will take an electrical charge. If an alternating voltage is applied, an alternating current will flow into and out of the insulator (in this case called a dielectric) as it charges and discharges with reversal of applied voltage. On alternating current circuits the charge is a maximum, but the current becomes zero, as the voltage reaches a maximum. The current change thus precedes the voltage change, or the current leads the voltage; this being opposite to inductance. The characteristics of being able to take an electrical charge is known as capacity (C) and is measured in Farads.

11.15. Capacitive Reactance – (Symbol Xc): When considered in an AC circuit with a definite frequency, capacitance results in a capacitive reactance which is measured in ohms. Capacitive reactance causes the current to lead the voltage by 90 electrical degrees. The value in ohms is determined by the formula:

$$X_C = 1/2\,\pi\,fc$$

Where:

f = Frequency
c = Capacitance (Farads)
π = 3.1416

11.16. Charge: There are two types of charge, positive (+, proton) and negative (–, electron). An atom with electrons missing is unbalanced—it has more protons than electronics and is, therefore, positively charged. The same analysis applies to an atom having more electrons than it should—it is negatively charged. Like charges repel each other. Unlike charges attract each other.

11.17. Circuit Breaker: A special switch used to protect electrical circuits is called a circuit breaker. It is generally designed to open or break the circuit when some abnormal condition, such as an overload occurs. The circuit breaker usually has a higher initial cost than a fused knife switch, but has the advantages of opening the circuit faster and can be reset easier after the cause of the overload has been removed. Circuit breakers are difficult to size as necessary to protect an engine–driven generator. A circuit breaker rating of 125% generator rating is usually used, however, engine power usually limits generator load to less than 125%.

11.18. Compound: A **chemical** combination of elements that cannot be separated by simple physical means such as by dissolving one out and leaving the others or by filtering or distillation, etc. There must be a chemical reaction to separate a compound.

11.19. Continuous Standby: The rating at which a generator set may be operated for the duration of a power outage. No overload capacity is guaranteed.

11.20. Cross Current Compensation: Cross current compensation is used to divide reactive kVA equally between generators operating in parallel, and is accomplished by a current transformer. Division of reactive kVA between AC generators operating in parallel is a function of generator excitation. When operating AC generators in parallel, it is necessary that the reactive kVA outputs of the individual generators be equalized. This is to prevent one generator from being overloaded by carrying all of the reactive kVA because its individual excitation is higher than that of the other machines. It is accomplished by the current transformer limiting or controlling the voltage sensitive element of each voltage regulator with reactive current. This reactive current divides the kVAR among the generators according to their rating and enables the generators to all operate at the same power factor. Frequently, reactive droop compensation is used without the cross–current connection.

11.21. Current: Current is a flow of electricity. DC flows from negative to positive. AC alternates in direction. The standard symbol for current is "I" and it is measured in Amperes (Amps). The current flow theory is used conventionally in power and the current direction is positive to negative—opposite the flow of electrons.

11.22. Cyclic Irregularity: Cyclic irregularity is the ratio of magnitude of fluctuation of speed over the average speed. This is a calculated valve based upon firing diagrams and the mass of the system. Torsional characteristics are not involved and the system is assumed rigid.

$$\text{Cyclic Irregularity Ratio} = \frac{\text{Max. Instantaneous Speed} - \text{Min. Instantaneous Speed}}{\text{Average Speed}}$$

Its application to specific problems is critical in very large, low speed engines driving generators having many poles (18 or 36), or small 4 or 6 pole sets having less than one firing stroke per 2 cycles, where the instantaneous speed of the flywheel may drop considerably between firing impulses.

11.23. Delta Connection: The delta connection is so named because it resembles the Greek letter. To make a delta connection, the finish end of the first winding is connected to the start of the second winding, the finish of the second winding is connected to the start of the third winding and the finished of the third winding is connected to he start of the first winding.

Modern generators are normally connected in a wye or star pattern rather than delta for several reasons. The delta–connected generator has no advantages over the wye–connected machine, and the wye machine has the advantage of being able to bring out the neutral wire. Also, in the delta–connected machine it is difficult to design the generator to keep the circulating currents low in magnitude. Normally the wye–connected machine will give better wave form characteristics than the delta–connected generator. In the wye machine the harmonics tend to cancel each other out when line–to–line voltage is checked between two legs or phases. In the delta–connected machine the line–to–line voltage is across one coil or set of coils and there is no cancellation of harmonic effects, except that the third harmonic and its multiples are shorted out, and do not appear in the output. Delta–connected generators are used to supply 120/240–volt, three–phase/single–phase, 4–wire systems.

11.24. Dielectric Test: National Electrical Manufacturers Association (NEMA) standards provide that each generator of 250 watts output or more be given the following high potential factory test to check generator insulation.

Stator Windings—Apply two times the normal voltage plus 1000–volts.
Field Windings—Apply ten times the exciter voltage, but in no case less than 1500–volts.

11.25. Direct Current – (Symbol DC): A current that flows in one direction only for a given voltage and electrical resistance. A direct current is usually constant in magnitude for a given load. Electricity is generated as alternating current in revolving machines. In DC generators the AC current is changed to direct current by commutation. While DC voltage is substantially constant in a DC generator, a slight ripple is due to commutation.

11.26. Distribution Panel: Multicircuit switchgear panel used to feed power to individual loads.

11.27. Drip–Proof: Per NEMA MG1–1.20, a drip–proof generator is an open machine in which the ventilating openings are so constructed that drops of liquid or solid particles falling on the machine at any angle not greater than 15 degrees from the vertical cannot enter the machine either directly or by striking and running along a horizontal or inwardly inclined surface.

11.28. Dual Range Generator: Any 10–wire or 12–wire generator can be connected such that the stator windings in each phase are in series or parallel. When in series, the output voltage will be high. When in parallel, the output voltage will be one–half of the high voltage, but the current capacity will be doubled. A typical rating would be 240/480–volt. If the machine is also broad range, a typical rating would be 208–240/ 416–480–volt.

11.29. Efficiency: Input times efficiency equals output divided by the output plus losses. Efficiencies of generators are commonly given at 4/4, 3/4, and 1/2 load. Unless otherwise stated, the efficiency of the generator is always based on the kVA and power factor at which it is rated.

11.30. Element: A substance which cannot be broken down into a simpler substance which will retain the original characteristics. For example, copper, hydrogen, and oxygen are all elements; they cannot be reduced to anything simpler without destroying their properties.

11.31. EMF: Electromotive Force. See Volt.

11.32. Exciter: Synchronous AC generators require DC field excitation current. Most such generators today are furnished with exciters which are AC generators having rectified output.

11.33. Flywheel Effect: Internal combustion engine–driven generator sets must be provided with flywheel effect to meet the following conditions:

1. Harmful torsional vibrations must be avoided;
2. Speed variation, when operating alone, must be reduced to a point where objectionable variations in voltage or frequency are avoided;
3. Operation in parallel with a large system must be possible.
4. The neutral frequency must differ from forcing frequencies, of generator sets with which it is operating in parallel, by at least 20%.

In accordance with present practice, it is the responsibility of the engine manufacturer or set assembler to determine that the proper flywheel effect is provided to meet the conditions outlined above. The generator manufacturer will provide information on shaft stiffness and other details which are required in these calculations.

11.34. Frequency – (Symbol Hz): The number of cycles per second the current alternates is called the frequency. Most common frequency in the United States is 60 Hz. 50 Hz current is used in most other countries. Generators are also made in special high frequencies for certain applications. The unit for measurement of frequency is the Hertz equivalent to one cycle per second.

11.35. Harmonics: Any irregularity in a wave form can be resolved into a fundamental sine wave of the system frequency and one or more sine waves of higher frequencies which modify the fundamental. In AC circuits only odd harmonics occur. The possible harmonics for various stator connections follow:

Connection	Grounded	Possible Harmonics
Wye	Yes	1, 3, 5, 7, 9, 11, etc.
Wye	No	1, 5, 7, 11, etc.
Delta		3, 9, 15, 21, etc (circulating) and 1, 5, 7, 9, etc. (line)

11.36. Impedance – (Symbol Z): The total opposition to the flow of alternating current in a circuit that contains resistance and reactance is called impedance. Strictly speaking the reactance component takes into account both the capacitive and inductive components, but for all practical purposes in power circuits, we can neglect the capacitive reactance (X_c).

Total Impedance = Z = $\sqrt{R^2 + (X_L - X_C)^2}$

R = pure resistance
X_L = inductive reactance
X_C = capacitive reactance

If we neglect X_C the formula reduces to:

$$\sqrt{R^2 + X_L^2}$$

11.37. Inductance (L): Any device with iron in the magnetic structure has what amounts to magnetic inertia. This inertia opposes any change in current. It is quite apparent on alternating current since the voltage is continually in instantaneous value and this inertia has the effect of continually causing change in current to a lag behind changes in voltage. The characteristic of a circuit which causes this magnetic inertia is known as self inductance; it is measured in Henries and the symbol is ”L.”

Inductive Reactance (XL): When considered in an AC circuit with a definite frequency, inductance results in an inductive reactance (XL), which is measured in ohms and is determined as follows:

$$X_L \text{ (ohms)} = 2 \pi f L$$

11.38. Inertia: Inertia means the resistance of a mass to a change in velocity. A mass in motion will tend to travel in a straight line and at the same speed unless acted upon by an external force. Inertia is the force that pushes you forward when an automobile is decelerating or comes to a sudden stop.

11.39. Interruptible Service: A plan whereby an electric utility, elects to interrupt service to a specific customer at any time. Special rates are often available to customers under such agreements.

11.40. Insulation: Insulating materials are used in all electrical machinery to isolate and maintain the flow of current through the conductors. Temperature influences the life of insulation. The failure of insulating materials is generally mechanical, resulting from extended exposure to moisture, foreign materials, and higher temperatures than the limiting temperature of the materials used. Most insulation used in today’s generators is Class F, with a permissible temperature rise of 189°F (105°C) continuous, and 234°F (130°C) standby over a 104°F (40°C) ambient.

11.41. Isochronous Governor: A governor that maintains constant engine speed from no–load to full–load. It is a zero–droop governor. Typical accuracy is +/– .25% of rated speed.

11.42. Kilowatt – (Symbol kW): Power is the rate of doing work. Electric power is expressed in Watts or kiloWatts (1000 Watts). One horsepower equals 0.746 kW or approximately 3/4 kW. Inversely one kW equals 1.34 horsepower. Actual power (kW) equals apparent power (kVA) times power factor (expressed as a decimal).

$$\text{Horsepower} = \frac{\text{kW}}{.746 \times \text{Generator Efficiency}}$$

To calculate the kW input of an electric motor:

$$\text{Kilowatts} = \frac{\text{Motor Horsepower} \times .746}{\text{Motor Efficiency}}$$

A rule of thumb based on 90% generator efficiency:

Engine hp = Generator kW x 1.5

For single–phase generator:

$$kW = \frac{\text{Volts x Amperes x Power Factor}}{1000}$$

For three–phase generator:

$$kW = \frac{\text{Volts x Amperes x Power Factor x} \sqrt{3}}{1000}$$

11.43. Kilowatt Hour – (Symbol kWH): The measure of electrical energy is the kilowatt hour. One kilowatt of electrical power consumed for one hour equals one kilowatt–hour (kWH) of electric energy. This energy can be measured by a kilowatt–hour meter which is a small, sensitive electric motor, the rotor speed of which is proportional to the kilowatts flowing in the circuit to which the meter is connected. Revolutions of the motor are transmitted through a gear train to pointers on a register dial calibrated in kWH. Kilowatt hour meters can be used to give approximate instantaneous kW load readings by measuring the rate of disc rotation.

11.44. Kilovolt–Amperes – (Symbol kVA): In AC circuits, kVA is the measure of the apparent power flowing in the circuit. To find the true or actual power (kW), the kVA must be multiplied by the power factor (expressed as a decimal).

11.45. Magnetism: A phenomenon of certain materials (iron, nickel, cobalt), such that, when the atoms are aligned within the materials, a field of force is set up which can effect other magnetic materials that are within that field. One end of a magnet is called the north pole and the other end is the south pole.

11.46. Magnetic Field: The lines of force due to the proper alignment of the atoms are called magnetic flux lines and make up the magnetic field. By convention, the lines begin at the north pole and end at the south pole.

11.47. Magnetizing Current: Transformers, motors and other electro–magnetic devices containing iron in the magnetic circuit must be magnetized in order to operate. It is customary to speak of the lagging inductive current as a magnetizing current.

11.48. Molecule: The smallest particle of a compound that retains the properties of that compound. A molecule is made up of two or more atoms depending on the compound. One molecule of water (H_2O) is made up of two hydrogen atoms and one oxygen atom.

11.49. National Electrical Code® – (NEC®): The National Electrical Code® is a volume of standard electrical rules prepared by the National Fire Protection Association. The code contains basic minimum provisions considered necessary for safety. These minimum rules are modified, expanded and interpreted by local electrical safety governing bodies. Local electrical and building inspectors in a particular community should be consulted for answers to specific questions and interpretation of the local codes covering a particular installation.

11.50. National Electrical Manufacturers Association – (NEMA): This is an organization of electrical manufacturers set up to provide limited information pertaining to certain types of electrical equipment. A main function of the organization is to establish uniform nomenclature throughout the industry and to promote manufacturing economics. NEMA Standards do not cover traction generators, arc welding generators or the self–regulated type generator because these are specialized types of equipment from manufacturers setting acceptable standards.

11.51. NEMA Design B: Normal–Torque, general purpose induction motors. These motors comprise about 90% of all induction motors.

11.52. NEMA Design C: High–Starting–Torque, low–starting–current motors—often used for starting and running loaded compressors, pumps, etc., where a high starting torque is required.

11.53. NEMA Design D: High–Starting–Torque, high–slip motors—are usually found in loads having a flywheel effect, such as elevators, hoists, punch presses, etc.

11.54. Ohm: The unit which represents the amount of electrical resistance or impedance to the flow of electric current.

11.55. Ohm's Law: This is the fundamental law of electricity. The current in any electrical circuit is inversely proportional to the resistance of the circuit and directly proportional to the electromotive force in the circuit. This law may be expressed in three ways:

For DC:

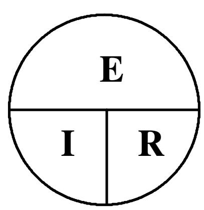
$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = IR$$

I = current is amperes
E = potential difference in volts
R = resistance in ohms
For AC:

$$I = \frac{E}{Z} \qquad Z = \frac{E}{I} \qquad E = IZ$$

I = current is amperes
E = potential difference in volts
Z = electrical impedance in ohms. For direct current Z is numerically equal to the resistance R. In AC circuits Z is made up of resistance R and reactance X.
(See impedance)

One volt is required to cause on ampere of electric current to flow through an impedance of one ohm.



With this diagram you cover the value desired with your finger and the proper mathematical relationship remains showing. For example, if you want to determine the resistance (R), you find $\frac{E}{I}$. Therefore, $\mathbf{R = \frac{E}{I}}$.

11.56. Overload: NEMA Standard MG1–16.41—Overload Capability – States: General purpose, prime power synchronous generators shall be capable of carrying 10% overload for two hours out of any 24. It is recognized that the temperature rise will differ from rated values when generators are subjected to overload condition.

11.57. Overspeed: NEMA Standards for Synchronous Generators MG1–16.46 – Overspeeds states: General purpose synchronous generators shall be so constructed that, in an emergency, not to exceed 1 minute, generators rated for 1800 rpm or less, will withstand an overspeed of 25% without mechanical injury.

11.58. Parallel Operation: Units to be paralleled must have the same frequency, the same number of phases, the same voltage, the same phase rotation. The latter merely means that the voltages across the terminals must reach their maximum and minimum values in the same order. Otherwise, the magnetic forces would try to turn the rotors in opposite directions.

11.59. Power: DC power is always the product of Volts times Amps and is expressed in Watts.

$$\text{Watts} = \text{Volts x Amps } (P = E \times I)$$

AC output of a generator is the apparent power and is equal to the Volts times Amps, as measured at the generator.

11.60. Apparent Power (kVA) = $\frac{EI}{1000}$

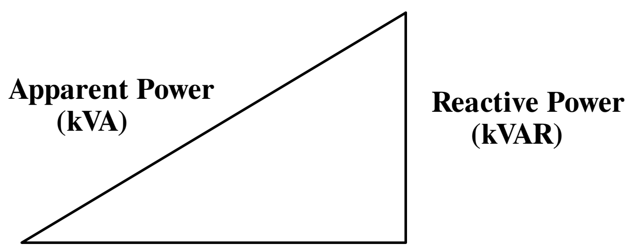
The apparent power (kVA) developed by the generator is used in two places:

1. Useable power for the load (kW).
2. Lost power due to reactance (kVAR) of the load.

The power used in the load is called the useable or real power and is expressed in Watts or kiloWatts (kW). Whenever the words Watts or kW is used, it means useable power.

The power lost because of the reactance is called reactive power or kilo Volt–Amps–reactive (kVAR). This lost power does no work.

The following triangle is a graphic representation of the relationships between apparent, real, and reactive power.



11.61. Power Conditioner: A device which removes undesirable transients and distortion from a power source.

11.62. Power Factor—(Symbol PF): Power factor is the ratio for expressing what part of the apparent power (kVA) flowing in an AC circuit is true power (kW).

$$\text{Power Factor} = \frac{\text{kW}}{\text{kVA}}$$

At unity power factor the kW and kVA are equal. At any power other than unity (leading or lagging power factor), the kVA are greater than the kW. When this is true there is a reactive component of the total kVA flowing in the circuit.

Mathematically, power factor is equal to the cosine of the angle by which the current leads or lags the voltage.

With a low power factor load, the reactive component is larger and thus more kVA capacity is required of the generator supplying the power. For a given kW load the increase in kVA caused by a low power factor means increased Amperes through the coils. The capacity (kVA) of generators, transformers, etc., is normally limited by the current capacity and heating limits of the coils.

11.63. Prime Power: The rating at which a generator may be operated continuously as a sole source of power, with intermittent overloads up to the standby rating.

11.64. Reactive Droop Compensation: A system similar to cross current compensation (see definition) in which an artificial voltage droop is introduced on reactive power, only as necessary to force generators to divide reactive load when operating in parallel. No cross–current connection between generators is required. This system is usually preferred to cross–current compensation.

11.65. Reactive Kilovolt–Amperes – (Symbol RkVA or kVAR): Reactive kVA is the measure of the reactive or magnetizing component of the total kVA flowing in a circuit. The out–of–phase or reactive component serves the important function of magnetizing the magnetic equipment, i.e., induction motors, transformers, etc., during a portion of each cycle. The magnitude of this component is determined by the proportion of magnetic equipment to the pure resistance loads which determines the amount of the current lags the voltage. Mathematically the tangent of the angle of lag is equal to the reactive kVA divided by the kW. In a three–phase circuit:

$$\text{kVAR} = \frac{\sqrt{3} \text{ x volts x reactive amperes}}{1000}$$

11.66. Rectifier: If only alternating current is available, it may be converted into direct current by using devices which offer a high resistance to the flow of current in one direction and a low resistance to the flow in the opposite direction. These devices are called rectifiers. A common rectifier is the diode.

11.67. Regulation: Voltage regulation is defined as the rise in voltage (field current and speed remaining constant), when full load is thrown off the generator.

$$\text{\% Voltage Regulation} = \frac{\text{(voltage at no load – voltage at full load) x 100}}{\text{voltage at full load}}$$

Speed regulation is similar.

$$\text{\% speed regulation} = \frac{\text{(no load rpm – full load rpm) x 100}}{\text{full load rpm}}$$

11.68. Resistance: Electrical resistance is that quality of an electric circuit that opposes the flow of current through it. In the electric circuit, the larger the diameter of the wires the lower will be their electrical resistance to the flow of current through them. Temperature also affects the resistance of electrical conductors to some extent. In most conductors (copper, aluminum, etc.) the resistance increases with temperature.

11.69. Resistor: A device used to limit current flow.

11.70. Rheostat: An adjustable resistance used for the purpose of controlling, limiting or adjusting the amount of current flow in a circuit is called a rheostat or potentiometer. Rheostats are often so constructed that the resistance in the circuit may be varied by turning a knob or moving a lever.

11.71. Right–Hand Rule: When using the "current flow theory" the current flows from positive to negative. If the thumb of the right hand is pointed along the conductor in the direction of current flow then the fingers, when wrapped around the conductor, will indicate the direction of the magnetic lines of force.

11.72. Short–Circuit Ratio: The ratio of the exciter field current for rated open circuit armature voltage at rated frequency to the field current for rated armature current on sustained symmetrical short circuit at rated frequency is called the short–circuit ratio of the generator.

11.73. Single–Phase: A single–phase AC circuit is generally served by 2 or 3 wires. Single–phase is most commonly used for lighting and fractional–horsepower loads. Single–phase may be obtained from a single–phase generator, from a three–phase generator between any phase and neutral, or between any to phases.

11.74. Star Connection: See Wye Connection.

11.75. Starting kVA: Induction motors demand more kVA to start than is required for steady state operation. "Starting kVA" is used to define the condition of this extra demand, which normally lasts for a brief period of seconds or less. It is a transient effect, but of great importance. Standard motors have a code letter indicating starting kVA per hp.

11.76. Synchronous Speed: The number of poles in an AC generator is directly related to the synchronous or operating speed. Any speed can be obtained that corresponds to any even number or pair of poles and the desired frequency.

$$N = \frac{120f}{P}$$

f = frequency in cycles per second
N = synchronous speed in RPM
P = Number of poles

60 Hz.		50 Hz.	
rpm	**Number of Poles**	**rpm**	**Number of Poles**
1800	4	1500	4
1200	6	1000	6
900	8		

To maintain rated frequency, the speed of the generator must be maintained as shown above.

11.77. Synchroscope: A synchroscope is an instrument for indicating when generators are in proper phase relation for connecting in parallel and at the same time showing whether the incoming generator is running fast or slow. The instrument has two independent circuits, one being connected to the incoming generator and the other to the bus. The magnetic fields set up by these two circuits cause the hand to rotate. When the hand comes to a standstill at the mark on the dial indicating synchronism, the switch connecting the generator to the bus line may be closed.

11.78. Telephone Influence Factor – (Symbol TIF): This is the measure of the inductive effect of a power system on nearby telephone circuits as represented by the noise level in the telephone receiver. Technically, the TIF of a three–phase synchronous machine is the ratio of the square root of the sum of the squares of the weighted RMS values of the fundamental and non–triple series harmonics to the TMS value of the normal no–load voltage wave. Telephone receivers are normally designed at a resonant frequency of approximately 1100 Hz. The human ear is very sensitive to the frequency of 1100 Hz. A high TIF indicates pressure of harmonics which show as a high pitched hum in a nearby telephone circuit. A 60–cycle pure sine wave has a TIF of unity. A commercially acceptable normal balanced TIF for generators with kVA ratings from 6.25 to 62.5 is 250. From 62.5 to 500 kVA, acceptable TIF is 150.

11.79. Temperature Rating: A generator with a temperature rise rating of 189°F (105°C), is one in which the manufacturer guarantees that the temperature of the generator will not rise more than 189°F (105°C) above an ambient (surrounding air) temperature of 104°F (40°C), when carrying full rated load continuously, at an altitude not exceeding 3300 ft. (1006m) above sea–level. The term "rated load" implies that the voltage and power factor are as called for by the nameplate of the generator. The same generator is permitted (by NEMA MG1–1640) to have a 234°F (130°C) temperature rise at a standby rating.

The temperature rise of 189°F (105°C) over ambient temperature given above, is based on measurement of rotor and stator temperature by resistance.

11.80. Three–Phase: A three–phase AC circuit is a combination of three electrical circuits with a voltage phase difference of 120 electrical degrees (1/3 cycle). A three–phase system may either be 3–wire, or 4–wire (3–wires and a neutral).

11.81. Time Constant: Any device with iron in the magnetic circuit has what amounts to magnetic inertia. This inertia opposes any change of current even though the voltage is changing. If a generator is short circuited, the time required for the short–circuit current to drop to 36.8% of the original maximum short–circuit current is called the generator time constant. This constant is important in determining the voltage change and voltage recovery of a generator when a sudden load change occurs.

11.82. Torsional Vibration: Torsional vibration may be found in the shafting of any rotating machinery in which there is cyclic torque variation. A torsional vibration is a periodic oscillation about a central axis. Should this vibration reach dangerous proportions at a so–called critical speed, serious damage could be inflicted on the associated machinery. The torsional stress of engine generator sets must be calculated and/or tested to assure satisfactory performance.

11.83. Uninterruptible Power Supply (UPS): A system designed to provide power without delay or transients during any period that the normal power supply is incapable of performing acceptably.

11.84. Volt – (Symbol V or E): The unit for measuring electric pressure or electromotive force required to force an electric current to flow. Voltage actually shows the difference in electromotive force between two points in a circuit. One volt is required to force one ampere through one ohm of resistance. In an AC circuit having a true sine wave the RMS (root mean square) or effective volts is equal to 0.707 times the maximum volts. The usual AC voltmeter generally measures effective volts, and unless otherwise specified, voltage values are always given as effective volts.

11.85. Voltages – Standard: The electrical manufacturing industry has standardized to a certain extent on voltages. Standard generator voltages are higher than motor or nominal voltages to allow for some voltage drop in the distribution lines. As a general rule, AC electric motors are designed to operate successfully on plus or minus 10% of nameplate or nominal voltage. Most externally regulated generators will operate within plus or minus 2% of nameplate voltage.

Alternating Current
Standard Voltage

Generator		Motor or Nominal
120	(1,4)	115
120/240	(2,3)	115/230
208/120	(2)	200
240	(1,4)	230
480/277	(2)	460
480	(1)	460
600	(1)	575
2400	(1)	2300
4160/2400	(2)	4000

(1) 3–phase, 3–wire

(2) 3–phase, 4–wire

(3) Single–phase, 3–wire

(4) Single–phase, 2–wire

11.86. Voltage Dip: ”Voltage Dip” is the momentary drop of generator output voltage that occurs whenever a load is added to the system. There is a momentary increase in output voltage whenever a load is removed from the system. This is called ”Voltage Rise.” ”Voltage Rise” is seldom of concern with an adequate voltage regulator.

11.87. Voltmeter: This instrument when connected across the line will indicate the potential difference in volts. Actually, these instruments usually operate on the same principle as an ammeter except that a high resistance is placed in series with the coil so that the current flow is limited when the meter is connected across the line. The current in the coil is therefore proportional to the line voltage. The scale is not uniformly divided, as on DC voltmeters, for the deflections are very nearly proportional to the square of the voltage. The divisions at the lower part of the scale are crowded so that poor precision is obtained. The divisions at the middle and upper portions of the scale, however, are usually such that they may be read with precision.

11.88. Watt: See kilowatt.

11.89. Wattmeter: Electric power is measured by means of a wattmeter. Because electric power is a function of current and voltage, a wattmeter must have two elements, one for current and the other for voltage. The power indicated by a wattmeter is a result of the voltage across the load, the current through the load, and the power factor on the load. In effect, the wattmeter multiplies the voltage, current and power factor to indicate the true power. When using a wattmeter, take all precautions mentioned for ammeters and voltmeters. In addition, make sure that neither the current nor voltage exceeds the wattmeter capacity. Test the circuit with a voltmeter and ammeter before connecting a wattmeter. The wattmeter scale deflection does not indicate whether the meter is overloaded or not. The voltage may be low and the current high and still indicate a true power within the meter scale limit, but the current element may be overloaded.

11.90. Wave Form: The shape of the voltage wave which a generator produces is largely under the control of the designer, although most machines are designed to produce waves that closely approximate the true sine wave. Such factors as hysteresis, rotor and stator slotting, and armature reactance prevent a perfect sine from being generated.

11.91. Wye Connection: In a wye or star–connected generator the three start ends of each single–phase winding are connected together to a common neutral point, and the opposite or finish ends are connected to the line terminals. When both low–voltage, single–phase loads and higher–voltage, three–phase loads are encountered, a line to the neutral or common point will serve as a common return circuit for all three phases, i.e., 120/208–volt, 3–phase, 4–wire machine. In a wye–connected machine the voltage from line to line is equal to the product of 1.73 and the line to neutral voltage. For example, in a 208–volt machine the line to neutral voltage is $\frac{208}{\sqrt{3}}$ or 120 volts.

With a 4–wire, 120/208–volt generator, motors can be operated on the 3–phase, 208–volt leads, and 120–volt lighting loads can be connected anywhere in the circuit between the various lines and the neutral. If this is done it is important to balance the 120–volt, single–phase load as much as possible so that all of the added lighting load is not connected to one single–phase leg or coil.

11.92. Wound–Rotor Motor: The wound–rotor or slip–ring induction motor is used when it is necessary to vary the rotor resistance in order to limit the starting current or to vary the motor speed. The high resistance is used for starting and when the motor comes up to speed the resistance is cut out. The running characteristics are about the same as a standard squirrel–cage motor. The wound–rotor motor gives high starting torque with comparatively low starting current. On the other hand, its initial and maintenance costs are high and the external resistance is bulky.

Normally a wound–rotor motor will have an instantaneous starting current of 150–160% of rated full–load current and the current during acceleration is approximately 125% of full–load current. With the high resistance in the starting circuit the power factor is high on start, so the usual limiting factor in the selection of a generator set is kW capacity of the engine–generator set.