ALTERNATING CURRENT

An alternating current (AC) is an electrical current where the magnitude and direction of the current varies cyclically, as opposed to direct current, where the direction of the current stays constant. The usual waveform of an AC power circuit is a sine wave, as this results in the most efficient transmission of energy. However in certain applications different waveforms are used, such as triangular or square waves.

Used generically, AC refers to the form in which electricity is delivered to businesses and residences. However, audio and radio signals carried on electrical wire are also examples of alternating current. In these applications, an important goal is often the recovery of information encoded (or modulated) onto the AC signal.

History

William Stanley Jr designed one of the first practical coils to produce alternating currents. His design was an early precursor of the modern transformer, called an induction coil. From 1881 to 1889, the system used today was devised by Nikola Tesla, George Westinghouse, Lucien Gaulard, John Gibbs, and Oliver Shallenger. These systems overcame the limitations imposed by using direct current, as found in the system that Thomas Edison first used to distribute electricity commercially.

The first long-distance transmission of alternating current took place in 1891 near Telluride, Colorado, followed a few months later in Germany. Thomas Edison strongly advocated the use of direct current (DC), having many patents in that technology, but eventually alternating current came into general use (see War of Currents). Charles Proteus Steinmetz of General Electric solved many of the problems associated with electricity generation and transmission using alternating current.

Distribution and domestic power supply

Main article: Electricity distribution

AC voltage can be stepped up or down by a transformer to a different voltage. High-voltage, direct current electric power transmission systems contrast with the more common alternating-current systems as a means for the bulk transmission of electrical power. However, these tend to be more expensive and less efficient than transformers, or did not exist
when Edison, Westinghouse and Tesla were designing their power systems.

Use of a higher voltage leads to more efficient transmission of power. The power losses in a conductor are a product of the square of the current and the resistance of the conductor, described by the formula $P = I^2R$. This means that when transmitting a fixed power on a given wire, if the current is doubled, the power loss will be four times greater. Since the power transmitted is equal to the product of the current, the voltage and the cosine of the phase difference ϕ ($P = IV\cos\phi$), the same amount of power can be transmitted with a lower current by increasing the voltage. Therefore it is advantageous when transmitting large amounts of power to distribute the power with extremely high voltages (sometimes as high as hundreds of kilovolts). However, high voltages also have disadvantages, the main ones being the increased danger to anyone who comes into contact with them, the extra insulation required, and generally increased difficulty in their safe handling. In the power plant the voltage is generated on three phase low voltage, with a frequency of either 50 or 60 hertz, and stepped up to a high voltage for distribution and stepped down, with a neutral, to a relatively low level for the consumer, generally around 200 V to 500 V between phases and 100 V to 250 V between each phase and the neutral.

Three-phase electrical generation is very common and is a more efficient use of commercial generators. Electrical energy is generated by rotating a coil inside a magnetic field, in large generators with a high capital cost. However, it is relatively simple and cost effective to include three separate coils in the generator stator(instead of one). These sets of coils are physically separated and at an angle of 120° to each other. Three current waveforms are produced that are 120° out of phase with each other, but of equal magnitude.

Three-phase systems are designed so that they are balanced at the load; if a load is correctly balanced no current will flow in the neutral point. Also, even in the worst-case unbalanced (linear) load, the neutral current will not exceed the highest of the phase currents. For three-phase at low (normal mains) voltages a four-wire system like this is normally used, reducing the cable requirements by one third over using a separate neutral per phase. When stepping down three-phase, a transformer with a Delta primary and a Star secondary is often used so there is no need for a neutral on the supply side.

For smaller customers (just how small varies by country and age of install) only a single phase and the neutral or two phases and the neutral are taken to the property. For larger installs all three phases and the neutral are taken to the main board. From a three-phase main board both single and three-phase circuits may lead off (and in some cases also circuits with two phases (not to be confused with two-phase) and a neutral are led off).

Three-wire single phase systems, with a single centre-tapped transformer giving two live conductors, is a common distribution scheme for residential and small commercial buildings in North America. A similar method is used for a different reason on construction sites in the UK. Small power tools and lighting are supposed to be supplied by a local center-tapped transformer with a voltage of 55V between each power conductor and the earth. This significantly reduces the risk of electric shock in the event that one of the live conductors becomes exposed through an equipment fault whilst still allowing a reasonable voltage for running the tools.

A third wire is usually (should be always but there are many older, non-compliant, or third-world installs where it is not) connected between the individual electrical appliances in the house and the main consumer unit ordistribution board. The third wire is known in Britain and most other English-speaking countries as the earth wire, but in (English-speaking) North America it is the ground wire. Exactly what happens to the ground wire before the main board varies, but there are three main possibilities, which are listed here by their European names:

TT (customer's earth not connected to neutral at all)

TN-S (neutral and earth run back separately to the transformer star point)

TN-C-S (neutral and earth are joined at the intake position).

There is also TN-C where neutral and earth are joined right through the install, but this is much less common than the others and requires special procedures to make it safe.

A system should be designed so that, in the event of a short to earth on any part of the system, some form of fuse or breaker will make the system safe. In a TT system the high earth loop impedance means that aResidual-Current Device (RCD) must be used. In other earthing systems this can be covered by the normal overcurrent protection devices. RCDs may still be used on such systems though as they can protect against small earth faults such as through a person.

AC power supply frequencies by country

Electrical equipment is made by the manufacturer to be used on a specific frequency, in general 50 or 60 hertz or for both frequencies. If specified for one frequency this equipment cannot and should not be used on the other frequency, because of burn out and therefore fire reasons.

The frequency of the electrical system varies by country; most electric power is generated at either 50 or 60 Hz. The 60 hertz countries are: American Samoa, Antigua and Barbuda, Aruba, Bahamas, Belize, Bermuda,Canada, Cayman Islands, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, French Polynesia,Guam, Guatemala, Guyana, Haiti, Honduras, South Korea, Marshall Islands, Mexico, Micronesia, Montserrat,Nicaragua, Northern Mariana Islands, Palau, Panama, Peru, Philippines, Puerto Rico, Saint Kitts and Nevis,Suriname, Taiwan, Trinidad and Tobago, Turks and Caicos Islands, United States, Venezuela, Virgin Islands(U.S.), Wake Island.[1]

The following countries have a mixture of 50 Hz and 60 Hz supplies: Bahrain, Brazil (mostly 60 Hz), Japan (60 Hz used in western prefectures), Liberia (now officially 50 Hz, formerly 60 Hz and many independent 60 Hz generating plants still exist). [2]

Also see List of countries with mains power plugs, voltages and frequencies.

Very early AC generating schemes used arbitrary frequencies based on convenience for steam engine, water turbine and generator design, since frequency was not critical for incandescent lighting loads. Frequencies between 16 2/3 Hz and 133 Hz were used on different systems, with lower frequencies favoured where loads were primarily composed of motors, and higher frequencies preferred to reduce lighting flicker. For example, the city of Coventry, England, in 1895 had a unique 87 Hz single-phase distribution system that was in use until 1906. Once induction motors became common, it was important to standardize frequency for compatibility with the customer's equipment. Standardizing on one frequency also, later, allowed interconnection of generating plants on a grid for economy and security of operation.

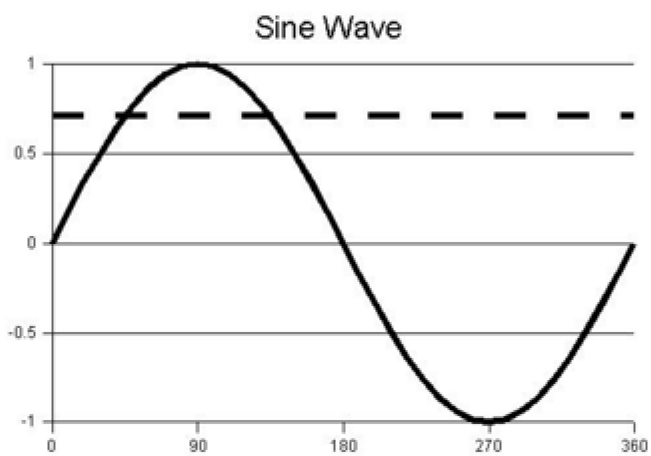
It is generally accepted that Nikola Tesla chose 60 hertz as the lowest frequency that would not cause street lighting to flicker visibly. The origin of the 50 hertz frequency used in other parts of the world is open to debate but seems likely to be a rounding off of 60 Hz to the 1-2-5-10 structure, called a set of preferred numbers, popular with metric standards.

Other frequencies were somewhat common in the first half of the 20th century, and remain in use in isolated cases today, often tied to the 60 Hz system via a rotary converter or static inverter frequency changer. 25 Hz power was used in Ontario, Quebec, the northern USA, and for railway electrification. In the 1950s, much of this electrical system, from the generators right through to household appliances, was converted and standardised to 60 Hz. Some 25 Hz generators still exist at the Beck 1 and Rankine generating stations nearNiagara Falls to provide power for large industrial customers who did not want to replace existing equipment; and some 25 Hz motors in New Orleans' floodwater pumps [3]. A low frequency eases the design of low speed electric motors, particularly for hoisting, crushing and rolling applications, and commutator-type traction motors for applications such as railways, but also causes a noticeable flicker in incandescent lighting and objectionable flicker of fluorescent lamps. 16.67 Hz power (1/3 of the mains frequency) is still used in some European rail systems, such as in Sweden and Switzerland.

Off-shore, textile industry, marine, computer mainframe, aircraft, and spacecraft applications sometimes use 400 Hz, for benefits of reduced weight of apparatus or higher motor speeds.

AC-powered appliances can give off a characteristic hum at the multiples of the frequencies of AC power that they use. Most countries have chosen their television standard to match (or at least approximate) their mains supply frequency. This helps prevent unfiltered powerline hum and magnetic interference from causing visible beat frequencies in the displayed picture.

Mathematics of AC voltages



A sine wave, 360 degrees in one cycle

Alternating currents are usually associated with alternating voltages. An AC voltage v can be described mathematically as a function of time by the following equation:

$$v(t) = A \times \sin(\omega t),$$

where

A is the amplitude in volts (also called the peak voltage),

ω is the angular frequency in radians per second, and

t is the time in seconds.

Since angular frequency is of more interest to mathematicians than to engineers, this is commonly rewritten as:

$$v(t) = A \times \sin(2\pi f t),$$

where

f is the frequency in hertz.

The peak-to-peak value of an AC voltage is defined as the difference between its positive peak and its negative peak. Since the maximum value of sin(x) is +1 and the minimum value is −1, an AC voltage swings between +A and −A. The peak-to-peak voltage, written as VP-P, is therefore (+A) − (−A) = 2 × A.

In power distribution, the AC voltage is nearly always given as a root mean square (rms) value, written Vrms.

For information in UK the 240 V AC supply is used (it should be noted that the UK is now officially 230 V +10% −6% but in reality voltages are still closer to 240 V than 230 V in most cases). It is so called because its rms value is (at least nominally) 240 V. This means that it has the same heating effect as 240 V DC.

The European Union (including the UK) have now officially harmonized on a supply of 230 V 50 Hz. However they made the tolerance bands very wide at ±10%. Some countries actually specify stricter standards than this for example the UK specifies 230 V +10% −6%. Most supplies to the old standards therefore conform to the new one and do not need to be changed.

Source : http://engineering.wikia.com/wiki/Alternating_current