

Introduction To Low Voltage AC Power Systems

Lesson 2 – Basic Theory



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Goal	IMO internal and external sales staff will have a basic introduction to Low Voltage AC systems.
Objectives	<ul style="list-style-type: none"> • Lesson 2 is intended to provide the participant with additional electro-technical theory, and should be attempted following successful completion of lesson 1. • This lesson introduces concepts, systems, equipment and devices that are common in electrical engineering. • This lesson further prepares the participant for dealing with simple electrical engineering questions from customers. • To widen the knowledge and awareness of the delegate as to what happens 'up-stream' of IMO products in a supply network.
Length	This lesson is intended to take approximately 1.5 hours
Content outline	<ol style="list-style-type: none"> 1. Getting Started (<i>same as general course pattern</i>) 2. Overview <ol style="list-style-type: none"> a. Course goal b. Chapters in this course c. General Principle of voltage generation d. Generating AC voltage e. Transmission of ac power f. Line and phase relationship g. 3-phase systems h. 1-phase systems i. Voltage and frequency variations

	j. Transformers k. Harmonics and waveform distortion
Learning Activities	Delegates will engage in the following activities at the end of this lesson <ul style="list-style-type: none">• Quiz• Test at later date
Evaluation Strategy	Delegates may be deemed to have an appropriate understanding of this course by obtaining at least 80% in the test.

Electrical supply systems

The most common type of electrical supply is a 3 phase alternating current system, because of its efficiency of transmitting power with respect to power distribution lines and the best use of space within the generators /alternators. Power is transmitted over long distances at voltages unsuitable for direct use by consumers, but by using transformers (these will be covered later) which are very efficient, the voltage levels can be stepped down to user compatible levels.

At the domestic consumer level the voltage is usually 'single phase' and obtained by splitting the output from a supply transformer into its three separate phases. This lesson covers the basic properties of single and three phase supply systems. Within Europe work is in progress to standardize on a single phase voltage.

General principle of voltage generation – The fundamental equation that relates magnetic flux and voltage induced in a coil is:-

$$e = n \frac{\delta\Phi}{\delta t}$$

where:- **e** = induced voltage

n = number of turns in the coil

$\delta\Phi$ which means a change of flux (**Φ**) in time **δt**

If the coil is stationary and the flux is obtained from a rotating magnet close to the coil, then the rate of change of flux will be cyclic. If the magnet is carefully shaped then for a constant rotational speed, then the induced voltage will be sinusoidal. This very simple arrangement will produce a single sin wave voltage (single phase voltage) at the coil ends, as shown in Figure 1 and 2.

Flux penetrating coil

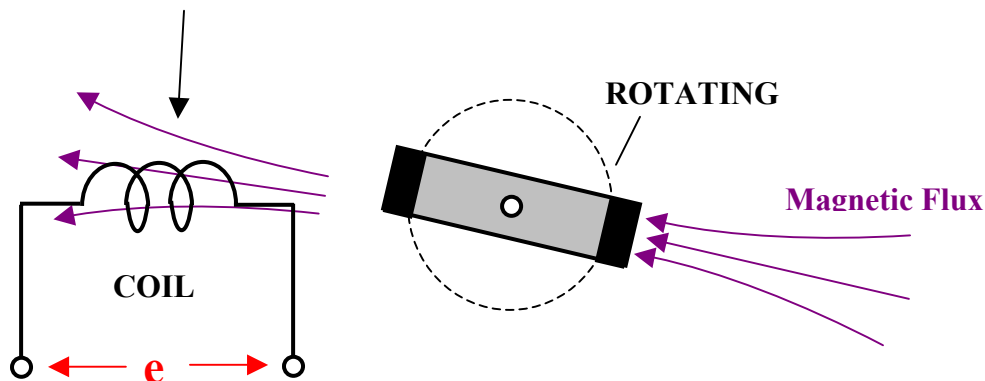


Figure 1. Simple single phase alternating voltage generator

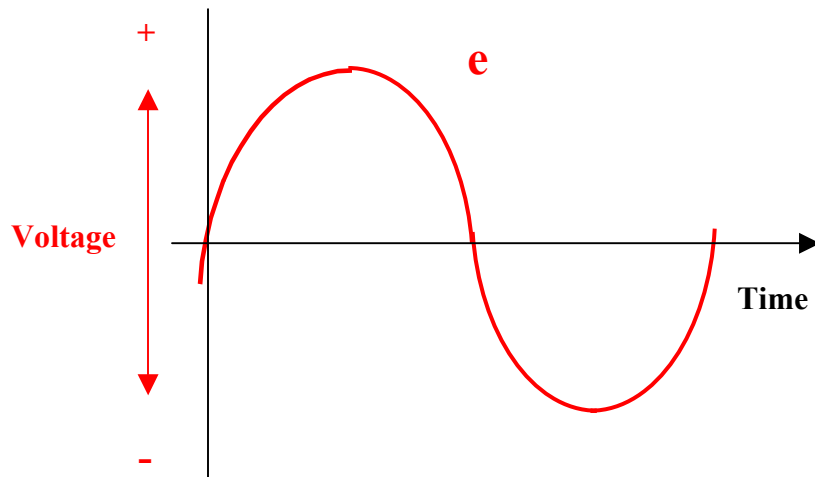


Figure 2. Voltage waveform for single-phase generator

Generation of 3-phase AC voltage — By adding two extra coils to the simple generator in Figure 1, two additional phases are created as shown in figure 3. If three coils are positioned 120° apart then the three voltages induced will be displaced by 120° with respect to each other as shown in Figure 4. It can be seen that the maximum voltage generated in the V-phase coil will occur one third of a revolution after the maximum voltage is generated in the U- phase coil. Similarly, the W- phase maximum voltage occurs one third of a revolution after the maximum voltage is generated in the V- phase coil.

The simple generator shown has three coils (windings). In practice each coil will be a set of coils distributed over a part of the **stator** (non moving part) of the generator, and opposite each set of coils will be a second set connected in series, giving six coil groups in total, so that the stator space is fully utilized. The arrangement shown in Figure 3 on the next page has two poles on the rotating field and this is usually the configuration of most large generators driven by steam or gas turbines. This configuration takes advantage of the **Prime Mover's** (the machine that is driving the generator) high running speed as well as the generator being economical with space.

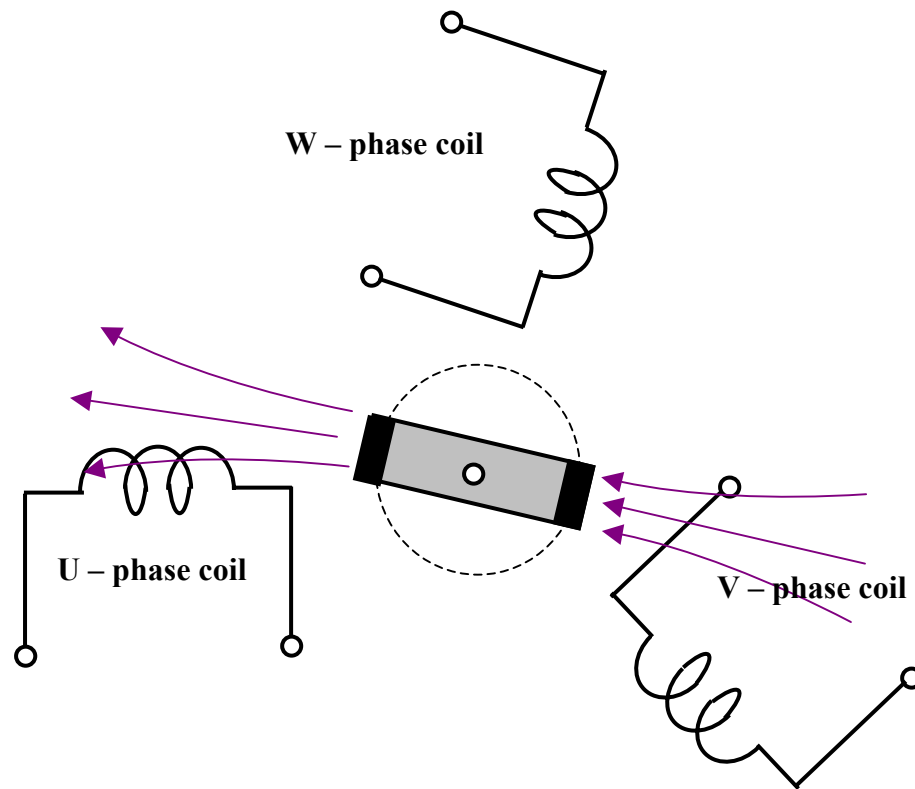


Figure 3. Simple 3-phase alternating voltage generator

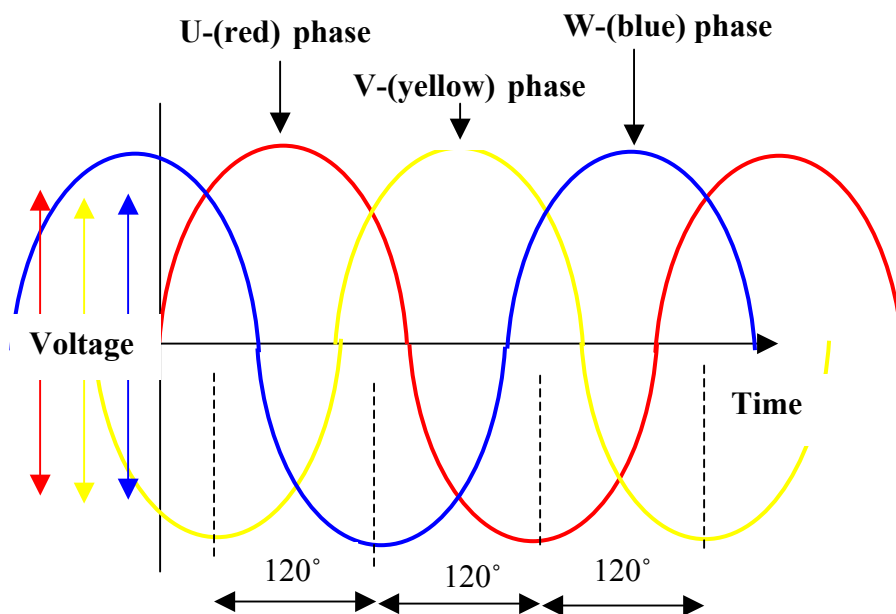


Figure 4. Voltage waveforms for 3-phase generator

More poles can be used and normally for each pole there will be three coil groups. 4 pole generators can be found in some power plants but other pole numbers are rare except for much higher pole numbers-20 or more-that are necessary for very slow running, large size hydroelectric generators.

The relationship between the pole number, speed of rotation and frequency is as follows:-

$$N = \frac{f}{P_p}$$

where:- N = speed (revs per second)

f = supply frequency (Hz)

P_p = number of pairs of poles

Transmission of 3 phase AC power — The simple generator shown in figure 3 can be connected to six separate wires (two per phase) for the purpose of transmitting power, as shown in Figure 5.

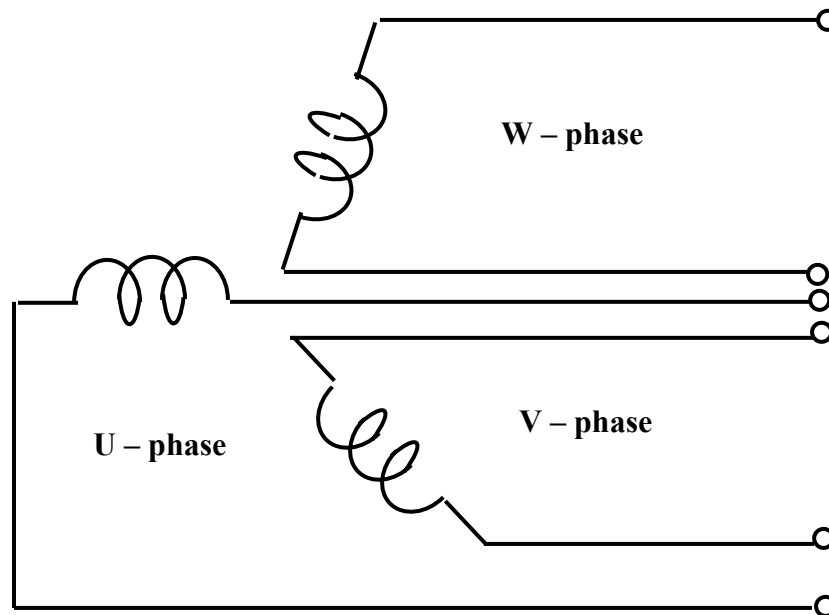


Figure 5. 3-phase, 6-wire connections to supply system

However, if the load that is to be connected to the generator is balanced, the currents in each phase can have the same waveforms as the voltages shown in Figure 4, and if this figure is studied it can be seen that the sum of the voltages at any time is always zero.

This will also apply to the current and therefore the three wires shown close together in the center of Figure 5 can have zero net current flowing. It follows that there is no need to retain these three wires and that the three groups of coils can have their inboard ends as shown in Figure 5, connected together. This point is commonly called the ‘**star**’ point or ‘**neutral**’ point, and the connection system is defined as star connected. The number of wires required therefore is now only three, as shown in figure 6 for the same power transmission capability as for the six-wire system.

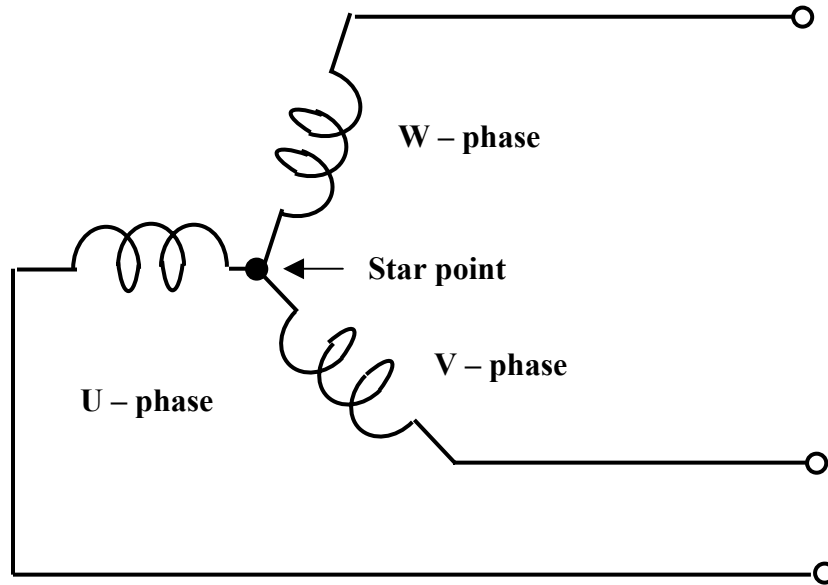


Figure 6. 3-phase, 3-wire connection to supply system

The star point may be connected to earth at the generator and a **neutral** wire may also be connected to the star point as shown in Figure 7, but this would only be for low voltage generators – not for typical power plant generators producing many thousands of volts.

For normal industrial applications the power supply will be 3-phase plus neutral or 3-phase only but for domestic single-phase requirements the system will revert to three separate phases at the supply end with the connected loads to each phase balanced as far as possible. In the supply system, transformers increase and decrease the voltage as appropriate (decreasing and increasing the currents – as voltage comes down, current goes up and visa-versa) to ensure the losses due to current flow are minimized; the highest voltages being used for high power transmission over long distances.

If an industrial consumer requires a high power input to a plant then the voltage may be high and commensurate with the rating of the equipment to be supplied. For domestic supplies the lowest voltage is used and usually from a single phase.

Line and phase relationships — The voltage between the supply wires of the system shown in Figure 6 is the combination of the voltages across two phases. The maximum voltage between any two wires will occur when the voltage in the third wire is zero.

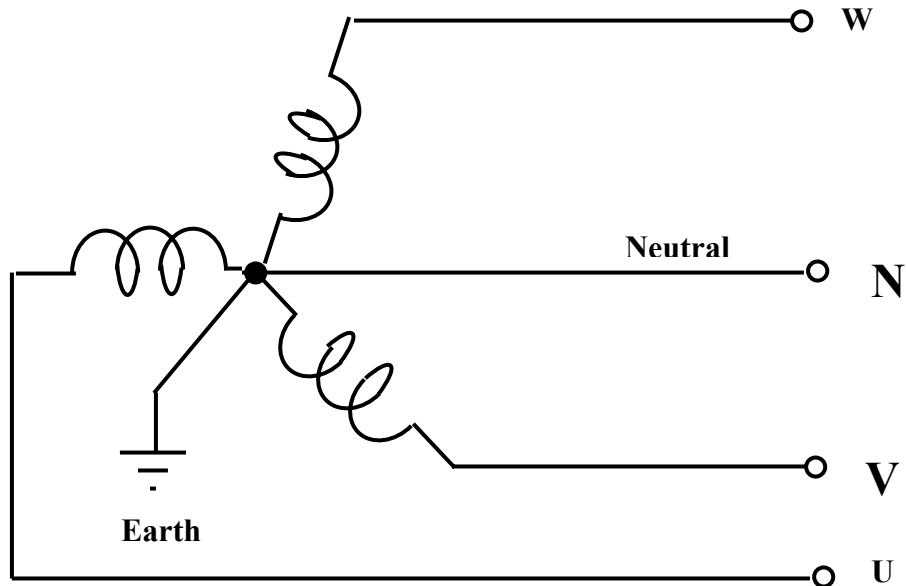
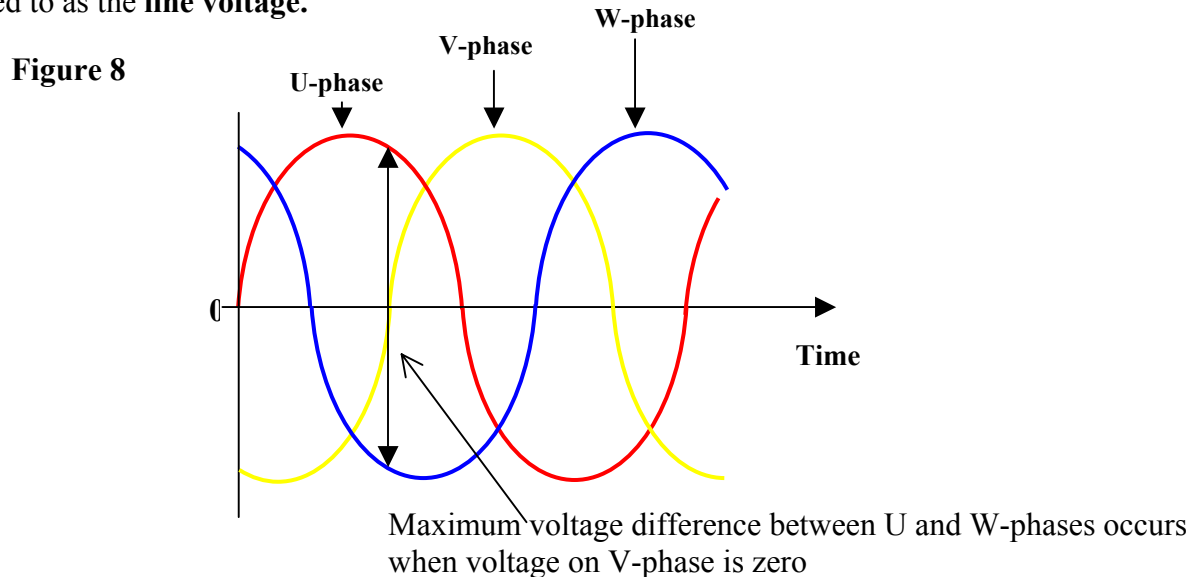


Figure 7. Typical 3-phase, 4-wire supply system

Referring to Figure 8, at the time when the V-phase voltage is zero the U-phase voltage is equivalent to the maximum voltage times $\cos 30^\circ$ and the W-phase voltage is the same value but in the reverse sense.

The voltage between the two wires U and W is thus $2 \cos 30^\circ$, that is **1.732** or $\sqrt{3}$ times the **phase voltage**. The voltage between the three supply wires or lines is normally referred to as the **line voltage**.



It should be noted that the peak voltages per phase in Figures 7 and 8 are not the voltages used to describe the system voltage; the root mean square (**r.m.s.**) is used conventionally. If for example, a system voltage is described as 3.3kV,

The **peak** value is:- $3.3\text{kV} \times \sqrt{2} = 4.67\text{kV}$,

The **r.m.s. phase** value is:- $3.3\text{kV} / \sqrt{3} = 1.9\text{kV}$

The **peak phase** value is:- $1.9\text{kV} \times \sqrt{2} = 2.69\text{kV}$.

3-phase voltage systems — The most common frequencies are 50Hz and 60Hz with a few older supply systems using 25Hz and 40Hz. 60Hz supplies are essentially found in North and South American countries but Korea and parts of Japan also supply at 60Hz.

The voltage level for industrial users may be as high as 22kV in plants requiring high power consumption. Most countries have a range of standard voltages, for example, within the UK high voltages are available at industrial premises can be 22kV, 11kV, 6.6kV and 3.3kV.

Standard voltages are given in IEC publication **IEC 38**. The lowest voltages available are based on the safety aspects of the equivalent single-phase voltage. For example, in the United Kingdom the safe single-phase voltage was set at **240V** giving the 3-phase equivalent as **415V** ($240 \times \sqrt{3}$). The most common 3-phase low voltages are 380V, 400V, 415V and 440V on 50Hz supplies. On 60Hz supplies, the most common voltages are 440V, 460V and 480V.

In Europe there is now a standard voltage which will be introduced in stages leading to a 400V, 3-phase system. **This will mean that in the next few years, the UK's standard industrial low voltage supply of 415V will be reduced to 400V, and domestic supplies will therefore also be reduced to 230V single phase.**

The majority of the 3-phase supply systems worldwide are of the 4-wire system type with an earthed neutral as shown in figure 7. In some isolated cases the neutral may not be earthed or there may not be a neutral wire. There are some countries that use a '**delta**' connected supply system of the form shown in Figure 9 sometimes with a neutral connected to the mid point of one of the phases or to the junction between two phases.

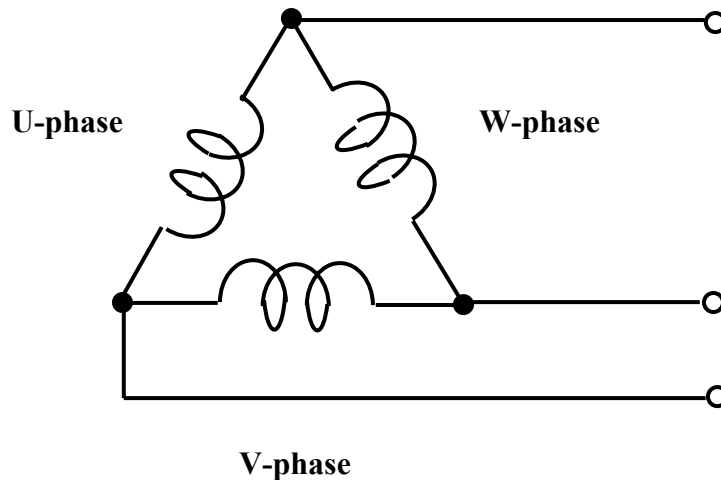


Figure 9. Delta connected supply system

In rare cases there are supply systems with an open delta connection, that is one of the connections not made and two wires used instead of one – in such case an earth is provided either at one of the other connections between phases or from the mid-point of one of the phases. Low voltage 3-phase supplies are generally available at commercial premises such as large shops and offices.

The incoming low voltage cable supplying the industrial or commercial premises will come from a local transformer and distribution unit, and will usually contain 4 separate wires – 3 phases and a neutral. The rms voltage between any two phases will be 415V and between any one phase and neutral, 240V. The cable will be of special construction and will be surrounded by a steel wire covering to protect the inner conductors from mechanical damage in the ground. This type of cable is known as PVCSWA (Poly-Vinyl Chloride Steel Wire Armour), and is used to bring power into domestic properties also, but having only 2 cores, 1 phase (Live) and the neutral. See figure 9a of the next page.

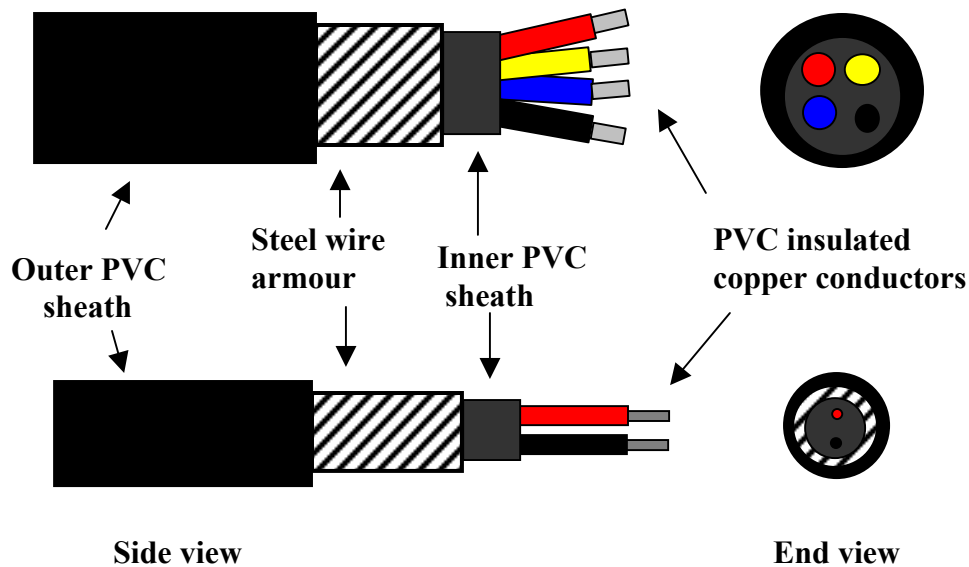


Figure 9a. Side views and cross sections of 3-phase and single-phase PVCSWA cables shown with different layers exposed for clarity

It is quite normal for the armour to be connected to earth at the supply end, and all of the property's safety earth wires to be connected to the armour at the point where the cable enters the building. If this is not sufficient, it is sometimes necessary to bury a metal plate or grid two or three meter's under ground, connect a metal rod to it that comes to the surface close to the property, and use this as the main earth point.

AC single-phase supplies — Single-phase supplies are invariably obtained from a 3-phase system by means of a transformer with a 3-phase input and three separate single-phase outputs. The connected load to each of the three separate phases will be balanced as far as possible. The frequency is of course identical to that of the 3-phase system of which it is part.

The majority on single-phase systems have a live and a neutral wire with the neutral wire earthed at some point in the system. Supplies to domestic customers may be two wires only but some supply systems have an additional earth wire. The majority of single-phase supply systems operate at a voltage within the range 200 – 250V.

Within Europe the majority of countries have operated a single-phase supply at 220V; with the notable exception of Great Britain operating at 240V and a few countries such as Northern Ireland and Norway operating at 230V.

In the interest of a single market within the European Community it has been decided that the voltage should be harmonized at 230V (corresponding to a 400V, 3-phase system) and regulations are in place to implement the change.

Supply regulations state the tolerance on the voltage level and up to the end of 1994 the 220V systems within Europe were generally $220\text{V} \pm 10\%$ (198 – 242V) and the 240V system in Great Britain $240\text{V} \pm 6\%$ (225.6 – 254.4V). From the beginning of 1995 the Great Britain nominal voltage was lowered to 230V with a tolerance of -6% to $+10\%$ (216.2 – 253V) whereas the European voltage was set at 230V with a tolerance of -10% to $+6\%$ (207 – 243.8V) from the same time. Within these voltage limits, existing equipment should function satisfactorily, but new equipment should be designed for a rated voltage of 230V for sale within the EC.

From the beginning of 2003 the voltage tolerance will be widened to $\pm 10\%$ across the EC giving the voltage range as 207 – 253V. It has yet to be decided whether the voltage tolerance should be reduced still further in future, but any such moves must be mutually agreed by member states. It is unlikely that the generated voltages will actually change in the short term as the agreed new voltage ranges encompass the nominal supply voltages in existence before the beginning of 1995.

Loads which are essentially resistive will take current directly related to the voltage, for example a light bulb for 230V will take an increased current from a 240V supply and so give more light and heat, but must still be adequate if supplied from 220V.

Loads which are essentially power output related will have a current inversely related to voltage. For example, a motor rated at 230V will normally take less current when run from a 240V supply but when run off a 220V supply the current is likely to increase and the temperature may also increase.

Some single-phase systems have an earthed phase mid-point at the supply transformer providing two different voltages, the full phase voltage between the ends of the phase and half the voltage between either phase end and earth. Such systems require three wires – two live and one earth. These systems are generally confined to North America where the system operates at 240/120V, 60Hz.

Voltage and frequency variations — Voltage and frequency at the supply point may vary from the rated values because of the varying nature of loads connected to the system. With the introduction of a move towards a standard low voltage within Europe, the allowable variation of voltage is subject to the restrictions described earlier under '*AC single phase supplies*' with respect to low voltages but whether these will also apply to higher voltages is uncertain.

If there is a substantial voltage drop in the cables (caused by current flowing through the cable resistance) and transformers connected between the load and the supply, when equipment like large motors are started, the voltage at the motor terminals may be less than the tolerance allows. Weaker supplies, for example those that are isolated from the mains, such as oilrigs, may have voltage variations outside those of mains systems and in addition may suffer large voltage drops when high power equipment is switched onto the supply.

Frequency tolerances vary considerably from country to country, from $\pm 0.1\text{Hz}$ to $\pm 5\text{Hz}$, with odd exceptions as high as $\pm 10\text{Hz}$. The UK allows $\pm 1\text{Hz}$ and this is a typically average value with most countries lying in the band $\pm 0.5\text{Hz}$ to $\pm 2\text{Hz}$. When loads are connected to a mains supply system the frequency is unlikely to drop, but in some cases of weak supplies the load may be sufficient to cause the generator to slow down and the frequency to decay. While a drop of frequency would not unduly affect the starting performance of a motor, it could have serious consequences for other equipment.

Transformers — All AC supply systems involve transformers in some part of the system, usually to convert the voltage from one level to another, but occasionally to provide isolation from the mains system.

Most common types of transformers consist of two coils wound onto a laminated iron core. The first coil is connected to the power supply and is known as the ‘**Primary**’ winding, and the second coil is connected to the load and called the ‘**Secondary**’ winding. Both coils are electrically isolated from each other, and power is transferred from one to the other by electro-magnetic induction through the iron core. The turns ratio between the primary winding ‘ N_1 ’ and the secondary winding ‘ N_2 ’ determines whether it is a ‘step-up’ or ‘step-down’ transformer, and the actual difference between input and output voltages.

Magnetic flux ‘ Φ ’ linking

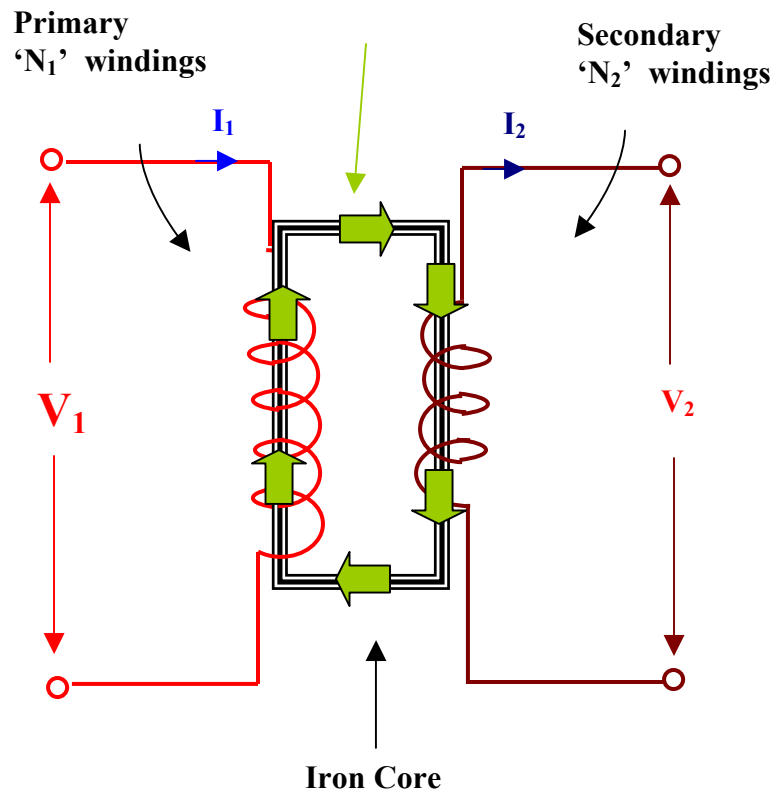


Figure 10. Diagram of Step-down transformer (only 1 phase of 3 shown for clarity)

Figure 10 on the previous page shows the general scheme for a single-phase input to single-phase output transformer, of small capacity (kVA). The diagram shows the two sets of coils wound onto a laminated iron core. N_1 and N_2 are the number of turns of wire on the primary and secondary windings respectively. The emf generated in either of the windings is proportional to the rate of change of flux linking it. So, if the flux ' Φ ' varies sinusoidally at a frequency ' f ', with a maximum value ' Φ_{\max} ', then the maximum value of the voltage induced in the secondary coil is given by: -

$$V_2 \max = N_2 \times 2\pi \times f \times \Phi_{\max}$$

The rms value of the secondary voltage is:-

$$V_2 = \frac{V_2 \max}{\sqrt{2}} \quad \text{so...}$$

$$V_2 = 4.44 N_2 f \Phi_{\max}$$

The voltage applied to the primary winding is equal and opposite to the induced emf, so that:-

$$V_1 = -4.44 N_1 f \Phi_{\max}$$

From these two equations we can see that the ratio of the magnitude of these voltages is:-

$$\frac{V_2}{V_1} = \frac{N_2}{N_1}$$

A step-up of voltage can be made if N_2 is larger than N_1 ; while a step-down results from N_2 being smaller than N_1 .

As only a small amount of power is dissipated in a transformer, we can consider the power entering it to be equal to the power leaving it. If the load on the transformer is taken at unity power factor ($\cos \phi = 1$) we can see that the power out, P_2 , is given by:-

$$P_2 = V_2 I_2$$

Similarly, the power entering the transformer, P_1 , is given by:-

$$P_1 = V_1 I_1$$

Since P_1 and P_2 are equal, we can also see that:-

$$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{N_1}{N_2}$$

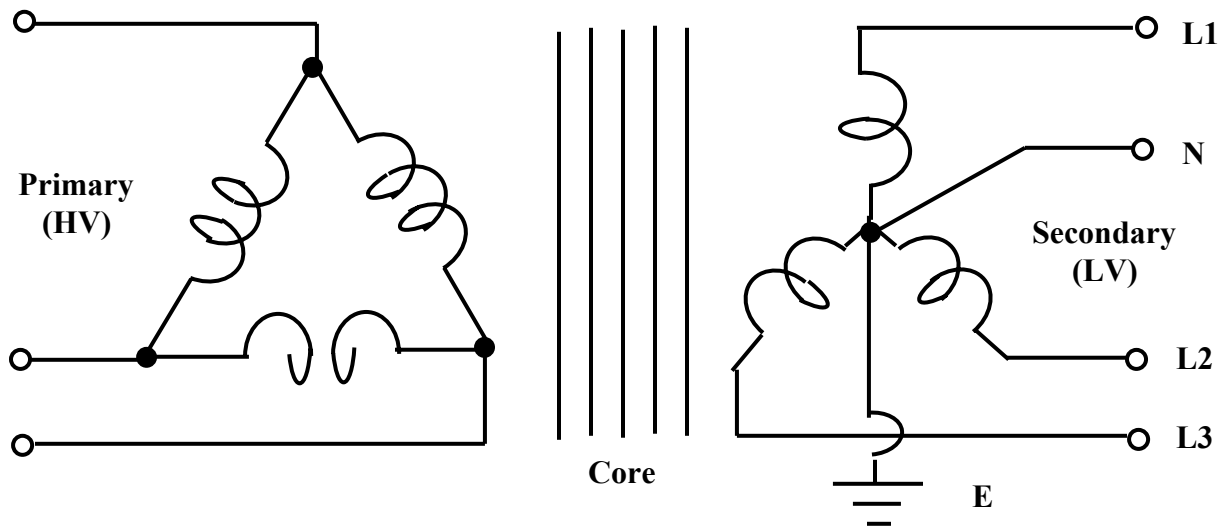


Figure 11. Typical arrangement of 11kV to 440V distribution transformer showing delta connected primary and star connected secondary with earthed neutral at star point.

Figure 11 shows a more realistic arrangement for a power distribution transformer with high voltage primary winding connected in delta format, and low voltage secondary winding connected in star. In practice the transformer may have more than one secondary winding, to give different voltages at the output terminals.

Mains transformers in power supply systems can take various forms. The most common is the mineral oil-filled type with a breather, and are designed with tubes on the external frame for natural cooling. The location of mains high voltage transformers is also important and often installations must have provisions for fluid leakage and fire control. Small transformers can also be used to change low voltage levels within a piece of load equipment such as a motor control center, to be compatible with small devices used only for system control. These are not oil filled but are instead open wound onto bobbins, and then insulated with special tapes. These devices are known as control transformers, and are very tiny compared with the large high voltage mains power versions.

Transformers are operated at a power factor ($\cos \phi$) determined by the load, and because this information will be unknown to the transformer manufacturer the maximum apparent power that is designed to deliver is quoted and thus are rated in terms of Volt-Amperes (VA or kVA). Under normal steady conditions transformers operate at high efficiency – usually close to 98% for power distribution transformers.

Under load, the secondary voltage of the transformer (the output) will drop compared with its no-load value, often referred to as **Regulation**. Regulation is normally expressed as the voltage drop on-load as a percentage of the no-load secondary voltage and can be 3% for small distribution transformers (less than 50kVA) improving to 1% for large

supply transformers. This variation in voltage is less than the tolerance allowed in the supply voltage value, and has little or no effect on most loads.

Harmonics and waveform distortion – In the first lesson we learned that the relationship between AC voltage and current is linear in a sin wave as shown in Figure 12 below.

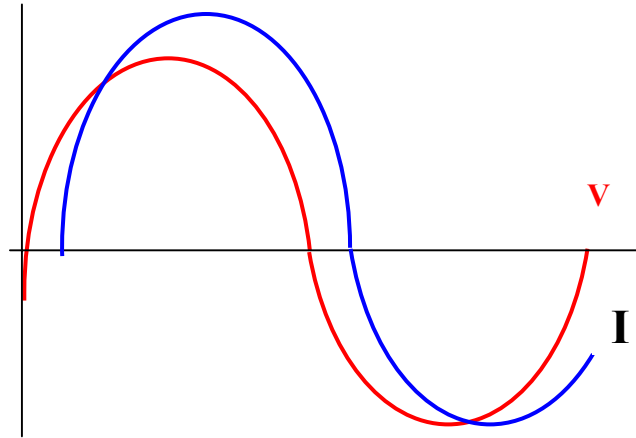


Figure 12. Linear relationship between voltage and current

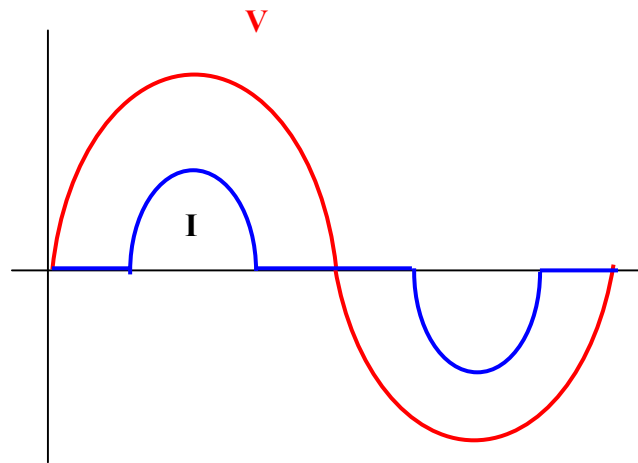


Figure 13. Non-linear relationship between voltage and current

Non-linear waveforms – If we look at Figure 13 we can see that the voltage is sinusoidal but the current is being drawn in short pulses. The positive and negative components of the wave shape begin to cancel each other out as we begin at the zero point and then part way through the first half cycle all of these components add up to form a peak. Then they diminish, cancel to zero again and repeat in the negative half cycle. This pulsed wave shape is typical of current drawn by personal computers, photocopiers, printers and single-phase electronic lighting ballasts (ordinary fluorescent lights).

Harmonics – Non-linear waveforms of all shapes are produced by currents flowing in a circuit that are at some multiple of the fundamental current. For example, if a fundamental sinusoidal current flows into a piece of equipment at 50Hz, but certain parts of the circuit contain **non-linear** devices then other currents will flow due to these devices at higher frequencies, say 150Hz, 550Hz, etc.

Modern technology used in both domestic and industrial electronic equipment use ‘switch-mode power supplies’ (SMPS) to supply internal devices and displays etc. Single or 3-phase power into the equipment is rectified (converted to dc) inside then processed accordingly. The rectification process involves use of non-linear devices called **Diodes** that tend to ‘bite’ chunks of current from the power input rather than draw it smoothly and sinusoidally. Two diodes are generally used per wire feeding the equipment - single-phase equipment having two wires (L and N) so four diodes in total. 3-phase equipment uses three wires (assuming no neutral wire) – so six diodes are required to convert to dc. Equipment that uses four-diode rectification is known as **4 pulse** and equipment using six diodes is known as **6 pulse**.

The most dominant harmonic, usually the one that has the largest amplitude (and causes the most problems) is determined simply by the rule: -

Most significant harmonic number = Pulse number – 1

As an example, an ordinary photocopying machine found in an office or a pc, are both supplied with single-phase ac power at 240V / 50Hz. These will be 4 pulse devices with the most dominant harmonic being the 3rd. ($4 - 1 = 3$).

Further to this, equipment such as an ac or dc variable frequency motor drive having a 3-phase input, would generate a large 5th harmonic ($6 - 1 = 5$).

In the case of the photocopier the 150Hz sine wave (3rd Harmonic) will add to the 50Hz fundamental and the resultant current waveform for the equipment will be distorted. See Figures 14 and 15.

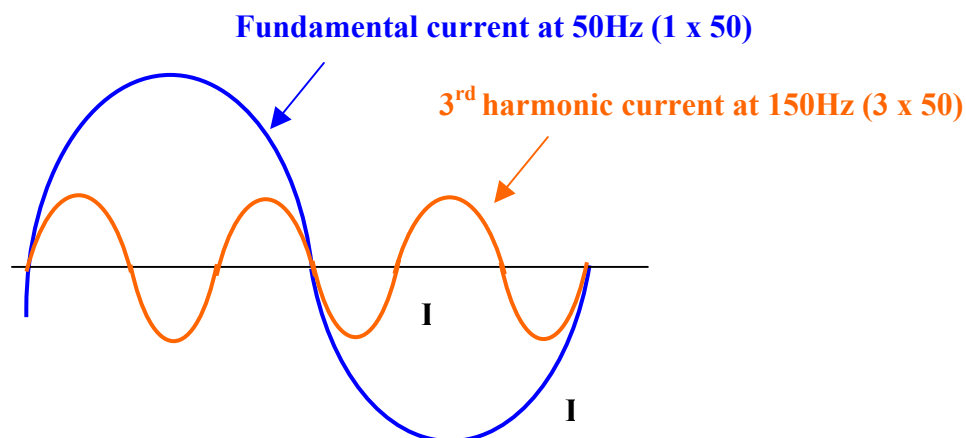


Figure 14. Fundamental and in-phase 3rd harmonic currents

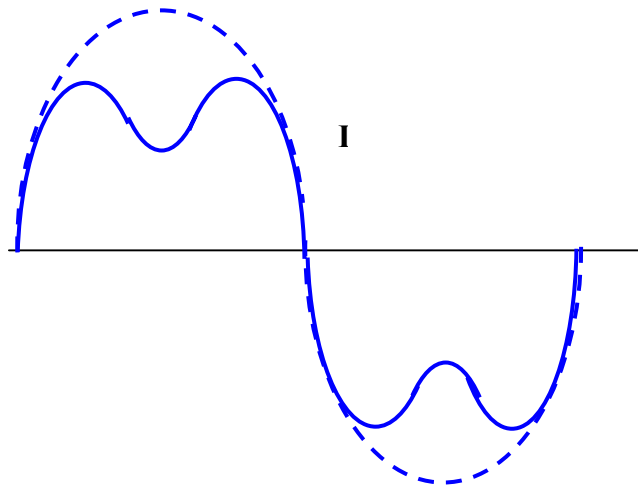


Figure 15. Distorted current waveform caused by addition of fundamental and in-phase 3rd harmonic currents

Alternatively, if the 3rd harmonic were to be drawn out of phase with the fundamental, the resulting composite waveform would look like Figures 16 and 17 on the next page.

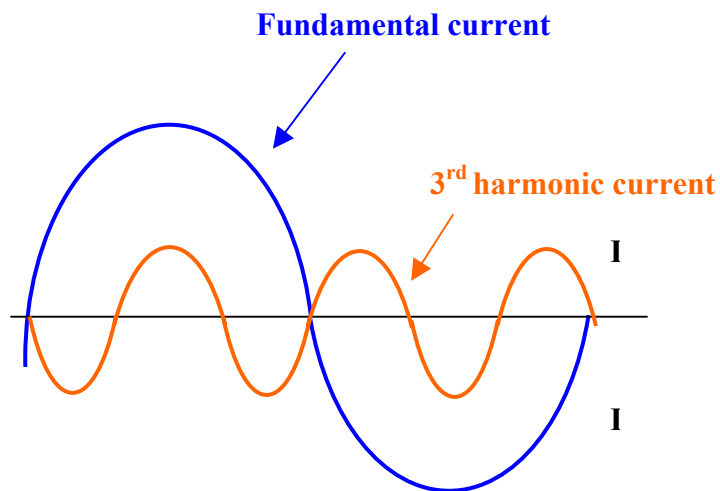


Figure 16. Fundamental and out of phase 3rd harmonic currents

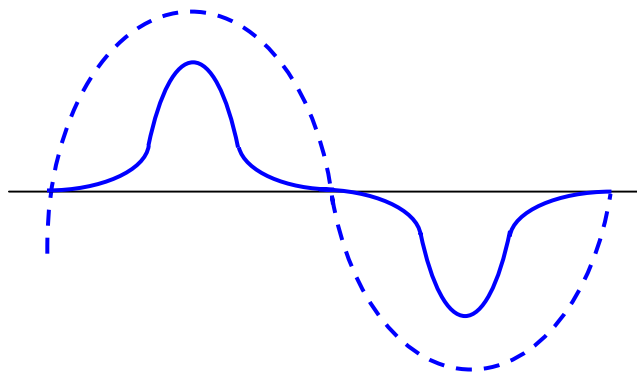


Figure 17. Distorted current waveform caused by addition of fundamental and out of phase 3rd harmonic currents

It must be remembered that many different harmonic frequencies will be present in non-linear loads, but after the most significant (dominant), the amplitudes generally fall away as the harmonic number – hence frequency, increases.

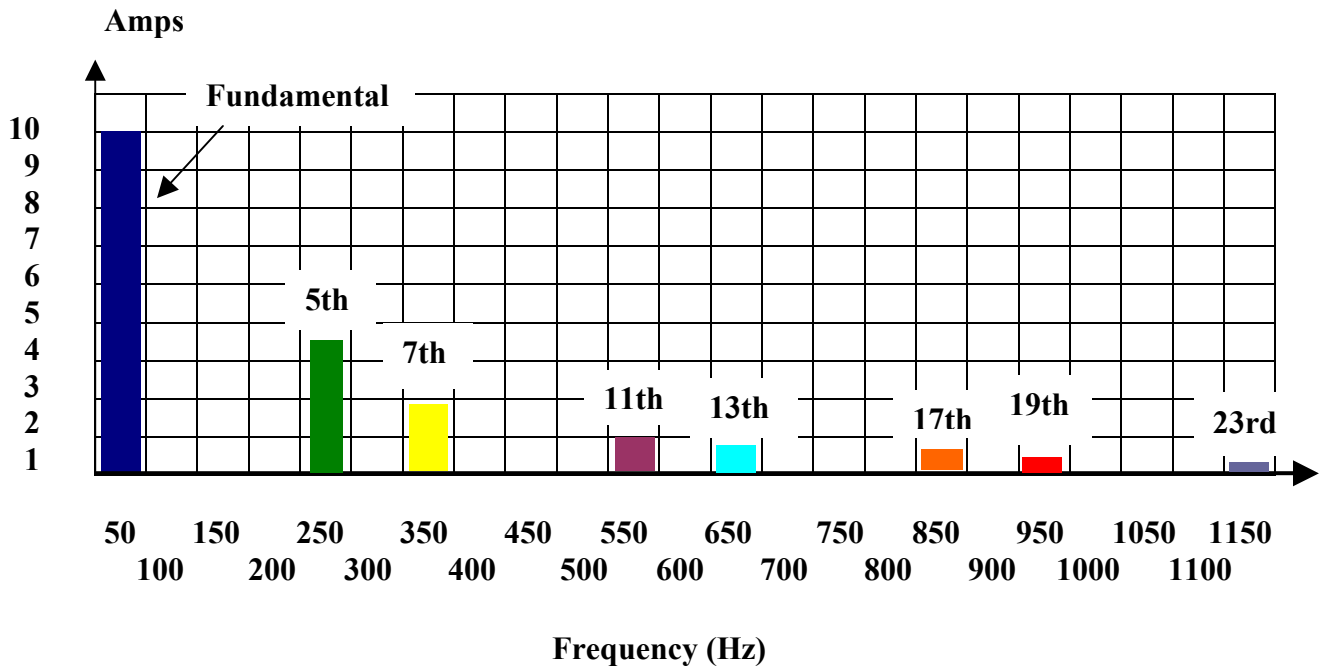


Figure 18. Spectrum analysis of typical 6 pulse, 3-phase non-linear load

Figure 18 shows a typical spectrum analysis of the different harmonics present and their frequencies and amplitudes, for a typical 6 pulse, 3-phase, non-linear load, such as a variable frequency motor drive. It shows that the dominant harmonic is the 5th, followed by the 7th, 11th, 13th, 17th, 19th, 23rd, etc, each diminishing in amplitude. In this case, we can see that the 3rd harmonic is zero, and every multiple of 3 cancels also.

Harmonic currents flowing in supply wires often cause the voltage sinwave that drives them to distort. See figure 19 on the next page.

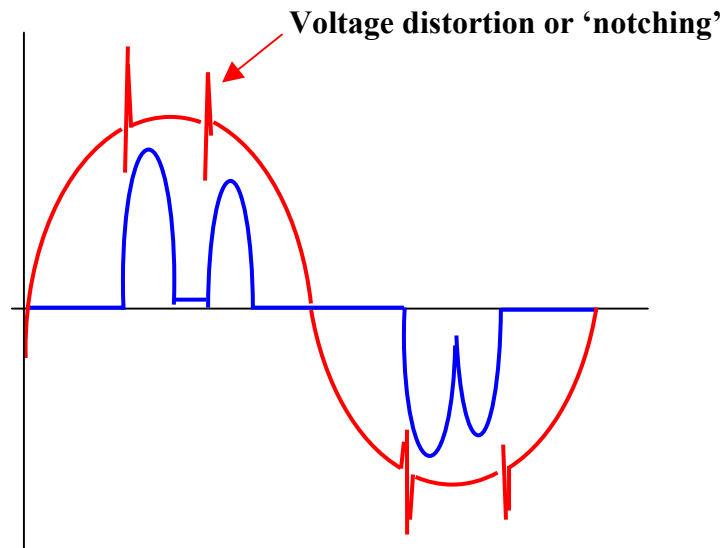


Figure 19. Typical voltage distortion as caused by harmonic currents

In the previous diagram we can see how a typical 6 pulse, 3-phase, non-linear load would distort its own input current, mainly by the addition of the 5th harmonic, but with contributions from all of the other harmonics present. As the non-linear devices within the equipment conduct, and the current is drawn suddenly, the voltage wave distorts momentarily before recovering and distorting again when the next current pulse occurs.

Voltage distortion or notching can cause all kinds of problems such as flickering lights, capacitors and other electronic components burning out, motors going backwards, interference to radio and TV etc.

Electricity supply companies take a serious view of consumers who excessively distort their power supplies, not only because of the problems associated with transformers and cables overheating due to harmonic currents circulating in the network, but because of disturbances to other users connected to the same power supply.

European **EMC Directive 89/336/EC** uses standards such as **EN61000-3-2** and **EN61000-3-3** that can be applied to new equipment to help ensure that compliance with EC limits for harmonic currents and voltage distortion respectively, are met. Other guidelines to supplement the European Directives in Great Britain include recommendations by the UK Electricity Supply Authority such as document **G5/4** which is intended to have a similar governing effect.

If the Standards and Directives are ignored, and a particular consumer is found by measurement to be excessively distorting the power supplies, i.e. in breach of document G5/4, the electricity supply company can remove the connection or in the case of new installations, reject the application for connection.

However much can be done to reduce the effect of harmonic distortion. Special harmonic filters (traps), chokes, reactors, etc can be used to lower distortion levels -either at equipment design stages or as retrofit engineering at a later date.

If a simple inductor (choke) is fitted in-line with the power input cables, the reactance of the power supply will increase as will the impedance, making it more difficult for harmonic currents to flow (the higher the frequency or harmonic number, the harder for it to flow).

For a 3-phase circuit containing harmonic currents, the total rms input current can be given by:-

$$I_{RMS} = \sqrt{ (I_F^2 + I_5^2 + I_7^2 + I_{11}^2 + I_{13}^2 +) } \text{ etc}$$

We can see by looking at Figure 18 that there are no even number harmonics, and all harmonics that are divisible by 3 cancel themselves out.

It is clear that if we reduce any or all of the harmonics in a circuit the rms input current will decrease also. This means that wires with smaller cross-sectional area can be used, with the associated cost reduction, and of course less current means cheaper electricity bills!

It is not only harmonic currents that can distort a voltage waveform but other outside influences as well. If, for example, lightning strikes an overhead high voltage power line somewhere locally, an **impulse** or **transient** that looks like a 'spike' can appear on the sin wave. See Figure 20 below.

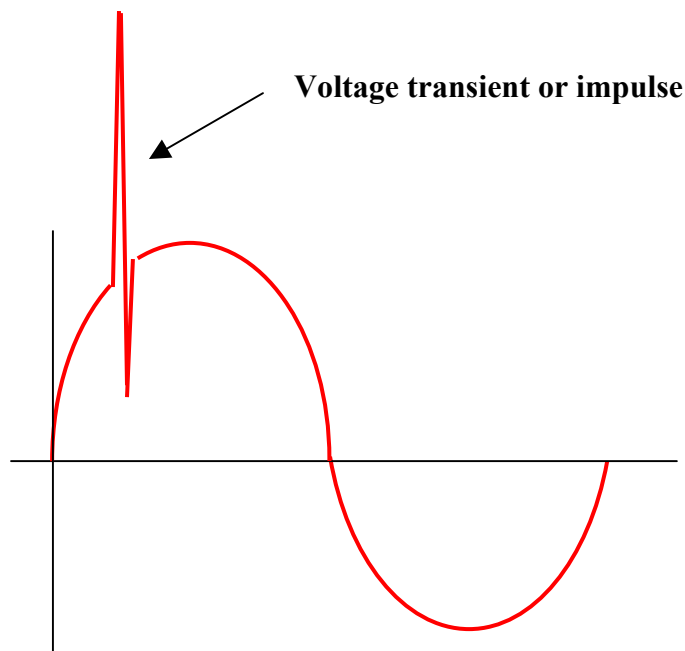


Figure 20. Typical voltage transient on sin wave.

In many cases this type of momentary over voltage could easily damage certain types of electrical equipment, especially if they contain electronic components such as capacitors, transistors, or integrated circuits (i.c.'s). The chance of damage depends on how much energy is carried by the impulse, i.e. how long that it lasts and the magnitude at its peak value. The whole supply network is subject to lightening strikes were it runs overhead on poles and pylons, and the electricity supply companies have some provision for isolating parts of the network in such an event.

General automatic protection acts quickly and cuts the power to local areas in the event of a fault. Power can be restored automatically from a central area control room for some faults, but for some isolated farms and communities it has to be restored manually by an engineer closing a set of fused contacts at the top of a pole.

For these reasons, it is always a sensible idea to take adequate precautions against power failure. For example, most IT managers insist on computer systems having both surge protection and some form of battery driven uninterruptible power supply (**UPS**) to back up computer systems in the event of loss of power. Also, hospitals, public buildings, water pumping stations, and large farms etc will use a standby generator driven from a diesel engine to supply emergency power. This can be arranged to 'kick-in' and be generating within seconds of the power loss occurring.

Introduction to AC Power Quiz

ASM Name:

Date:

Time allocated:

Time Taken:

1. What is the name given to magnetic energy?

(Answer)

2. How far apart are 3-phase generators windings?

(Answer)

3. What do we call the part of the generator that doesn't move?

(Answer)

4. At which point on the windings is the generator earthed?

(Answer)

5. What is rms phase value of a 415V supply system?

(Answer)

6. In a 3-phase system, when the voltage across any two wires is maximum, what is the voltage on the third wire?

(Answer)

7. What do the letters r.m.s. Stand for?

(Answer)

8. What is the supply frequency in the USA?

(Answer)

9. What does SWA stand for in PVCSWA?

(Answer)

10. Name TWO places that a consumer can make his safety earth connection?

(Answer)

11. From 2003, what is the highest domestic voltage allowed in the EC?

(Answer)

12. What is the allowable min and max frequency in the UK?

(Answer)

13. Name two common uses for a transformer?

(Answer)

14. By what method does the transformer secondary winding become energised?

(Answer)

15. In a step-down transformer, which winding has more turns?

(Answer)

16. How is a transformer rated (How do we quote its electrical size)?

(Answer)

17. What do we call the drop in secondary voltage when a transformer is on load?

(Answer)

18. Which is the largest harmonic found in a 3-phase, 6 pulse diode rectifier?

(Answer)

19. What device can be used to reduce harmonic current?

(Answer)

20. What is a 'U.P.S.' ?

(Answer)