DEFINITIONS ABOUT THREE-PHASE VOLTAGES

If you look at the wave and phasor diagrams in figure 14.1 b and c it should be clear that if the three phases are added together the result is that the voltages cancel each other out and VR + VY + VB = 0V. Therefore, if one end of each coil (R1, Y2 & B3 from figure 4.1a) are connected together a common neutral line at zero potential is created and the result is called a 4-wire 3-phase supply.

Figure 4.2a shows how the generator (or transformer) coils can be connected to give a 4-wire supply, this configuration is called a star, wye or Y connection and the point x is called the neutral point, star point or zero point. Figure 4.2b shows an alternative connection for the generator coils, known as a delta or mesh connection, this configuration has no neutral wire and provides a 3-phase 3-wire supply.

4-wire supplies are normally used to distribute domestic supplies since they can provide an earthed neutral. 3-wire systems are more commonly used for the transmission of high voltage supplies between substations because money is saved by not providing a neutral wire. If we consider a 4-wire supply we can see that there are 4 possible voltage supplies available, these are shown in figure 4.3.
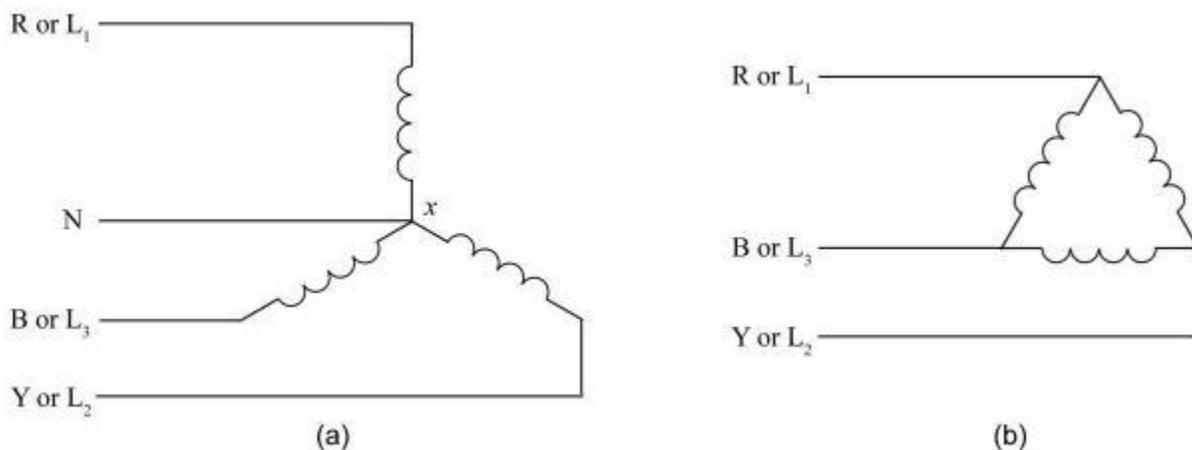

Figure 4.2: Three phase generator coils: (a) star, wye or Y connection ; (b) Delta connection;

The power supplies shown in figure 4.3 are:

The three phase wires together give a 3-phase 3-wire supply suitable for heavy machinery such as

3-phase motors. With a 240V supply in each line the 3-phase supply has an RMS voltage of   240√3 = 415V. (The mathematical derivation of why √3 is used is too complex for this text)

Three single-phase 240V supplies are available between each phase line and the neutral wire.

3-phase 415V   3 single-phase   3 single phase
3-wire supply   240V supplies   415V supply

3-phase 415V 4-wire supply
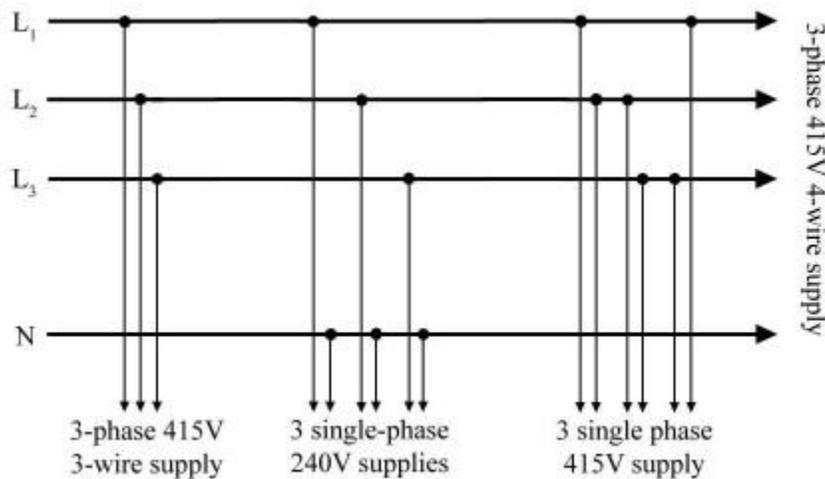
The three phase single-phase 415V supplies are available between any of the three phases.

The wave diagram for the potential difference between two 240V lines, 120° out of phase is shown in   figure 13.11b. (Note that the PD when a load is connected between phase lines is one voltage minus the other voltage, the resultant voltage when two phase lines are connected together is the line voltages added together (figure 4.4a).)

The three phase lines and the neutral together give a 3-phase 4-wire supply with a RMS voltage of 240√3 = 415V.

Loads can be connected to a 3-phase supply using the same two methods used for generator coils; that is star and delta. Figure 4.5 shows these connections. The current that flows in the lines is called the line current (IL) and the PD between any two phase lines is called the line voltage (UL).

The current in each load is called the phase current (IP) and the PD across each load is called the phase voltage (UP).

For a balanced system:

• Each load has the same magnitude of impedance;

• Each load impedance has the same phase angle;

• Each phase voltage (and current) is equal in magnitude;

• Each phase voltage is displaced by 120° from each other

The example in section 2.5 shows a analogous system for a DC supply where the branch containing R3 is the equivalent to the neutral wire. When the system is balanced no current flows through R3, only when the system becomes unbalanced does any current flow through this resistor.

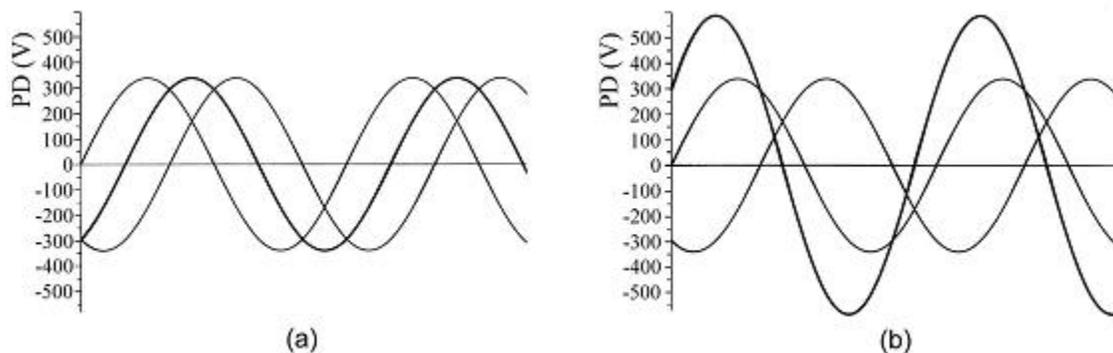(a)   (b)

Figure 4.4: The wave diagrams for: (a) adding together two 240V lines that are 120° out of phase to find the voltage supply when two lines are connected to the same point; (b) subtracting two 240V lines that are 120° out of phase to find the PD between the lines. The resultant is shown as a bolder line. It is interesting to note that the potential difference

between any two phase lines at U volts is √3U volts whereas the same two phases added together result in a voltage of U.

Figure 4.5a shows that for a star connected loads the PD across any load is the PD between the phase line connected to it and the neutral, however the line voltage will be greater than this because it is the PD between two phase lines. The current through the load will be the same as the line current. Thus for balanced star connected loads:

$$U_L = \sqrt{3}\,U_P$$
$$I_L = I_P$$

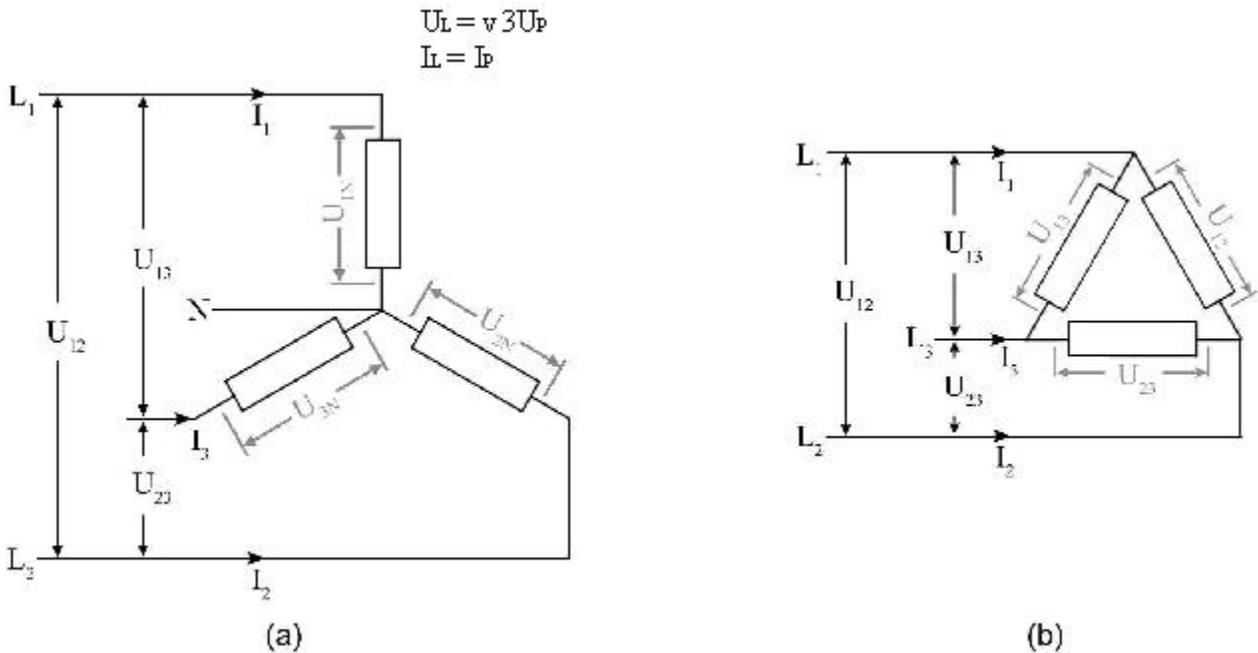(a)   (b)

Figure 4.5: 3-phase load connections: (a) a 4-wire star connection (note that a 3-phase wire connection is also possible when the neutral wire is left out); (b) a 3-wire delta connection. The line voltages are shown in black and the phase voltages are shown in grey.

Thus for a balanced system with 240V lines UL = 415V, and UP = 240V. For a balanced system no neutral wire is needed and even in a star supply the neutral wire can be left out. Only when the star connected loads are unbalanced will any current flow down the neutral, in a balanced system one of the other lines will always be at a lower potential than the neutral and the current will 'return' down this type of load connection is usually used for domestic distributions, where houses connect to one phase line and the neutral. If more houses are connected to one line than the others the loads become unbalanced and the neutral wire carries current.

Figure 14.5b shows that for delta connected systems of loads the phase voltage is equal to the difference between two lines. The phase current for each load is coming from two lines (because each load is connected to two lines) and will be more than the line current. Thus for delta connected loads:

UL = UP
IL = √3IP

Thus for a balances system with 240V lines UL = UP = 415V. This method of load connection is usually only used for machines with windings such as 3-phase motors which have three identical windings, since the absence of a neutral can means that unbalanced loads can cause problems.

$$P = 3U_PI_P \cos \phi$$

But $\quad I_P = I_L \quad$ and $\quad U_P = \dfrac{U_L}{\sqrt{3}}$

Therefore: $\quad P = 3\dfrac{U_L}{\sqrt{3}}I_L \cos\phi = \sqrt{3}U_LI_L \cos\phi$

For a balance delta connected load: $\quad P = 3U_PI_P \cos \phi$

But $\quad U_P = U_L \quad$ and $\quad I_P = \dfrac{I_L}{\sqrt{3}}$

Therefore: $\quad P = 3U_LI_L \cos\phi = \sqrt{3}U_LI_L \cos\phi$

Source : http://mediatoget.blogspot.in/2011/07/definitions-about-three-phase-voltages.html