<u>Polyphase Signals</u>

1. Generation of Polyphase Signal:

The kind of alternating currents and voltages discussed in AC signal generation are known as single-phase voltage and current, because they consist of a single alternating current and voltage wave. A single-phase alternator is diagrammatically depicted in Fig. 1 and it is shown to have one armature winding only. But if the number of armature windings is increased, then it becomes polyphase alternator and it produces as many independent voltage waves as the number of windings or phases. These windings are displaced from one another by equal angles, the values of these angles being determined by the number of phases or windings. In fact, the word ‘polyphase’ means poly (*i.e.* many or numerous) and phases (*i.e.* winding or circuit).

In a two-phase alternator, the armature windings are displaced 90 electrical degrees apart. A 3-phase alternator, as the name shows, has three independent armature windings which are 120 electrical degrees apart. Hence, the voltages induced in the three windings are 120° apart in time phase.

With the exception of two-phase windings, it can be stated that, in general, the electrical displacement between different phases is 360/n where n is the number of phases or windings. Three-phase systems are the most common, although, for certain special jobs, greater number of phases is also used. For example, almost all mercury-arc rectifiers for power purposes are either six-phase or twelve-phase and most of the rotary converters in use are six-phase. All modern generators are practically three-phase. For transmitting large amounts of power, three-phase is invariably used. The reasons for the immense popularity of three-phase apparatus are that ***(i)*** it is more efficient ***(ii)*** it uses less material for a given capacity and ***(iii)*** it costs less than single-phase apparatus etc.

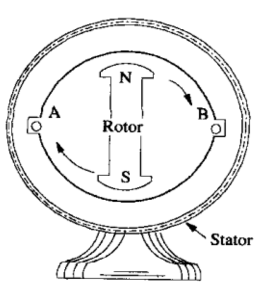

Fig. 1

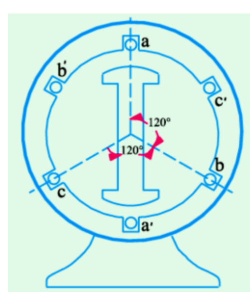

Fig. 2

In Fig. 2 is shown a two-pole, stationary-armature, rotating-field type three-phase alternator. It has three armature coils *aa'*, *bb'* and *cc'* displaced 120° apart from one another. With the position and clockwise rotation of the poles as indicated in Fig. 2a, it is found that the e.m.f. induced in conductor '*a*' for coil *aa'* is maximum and its direction* is away from the reader. The e.m.f. in conductor '*b*' of coil *bb'* would be maximum and away from the reader when the N-pole has turned through 120° *i.e.* when *N-S* axis lies along *bb'*. It is clear that the induced e.m.f. in conductor '*b*' reaches its maximum value 120° later than the maximum value in conductor '*a*'. In the like manner, the maximum e.m.f. induced (in the direction away from the reader) in conductor '*c*' would occur 120° later than that in '*b*' or 240° later than that in '*a*'. Thus the three coils have three e.m.fs. induced in them which are similar in all respects except that they are 120° out of time phase with one another as pictured in Fig. 3. Each voltage wave is assumed to be sinusoidal and having maximum value of *Em*.

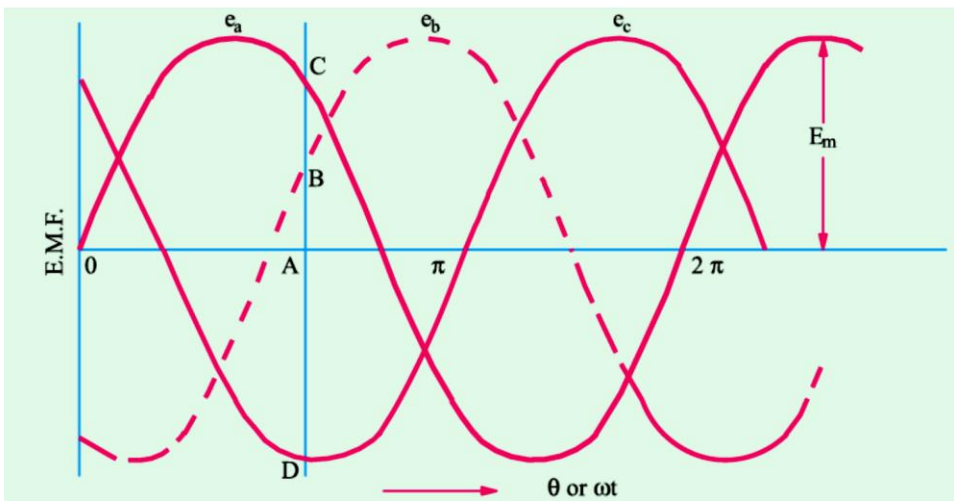

Fig. 3

$$e_a = E_m \sin \omega t \quad \ldots (i)$$
$$e_b = E_m \sin(\omega t - 120°) \quad \ldots (ii)$$
$$e_c = E_m \sin(\omega t - 240°) \quad \ldots (iii)$$

Alternating voltages may be represented by revolving vectors which indicate their maximum values (or r.m.s. values if desired). The actual values of these voltages vary from peak positive to zero and to peak negative values in one revolution of the vectors. In Fig. 4 are shown the three vectors representing the r.m.s. voltages of the three phases *Ea*, *Eb* and *Ec* (in the present case *Ea* = *Eb* = *Ec* = *E*, say).

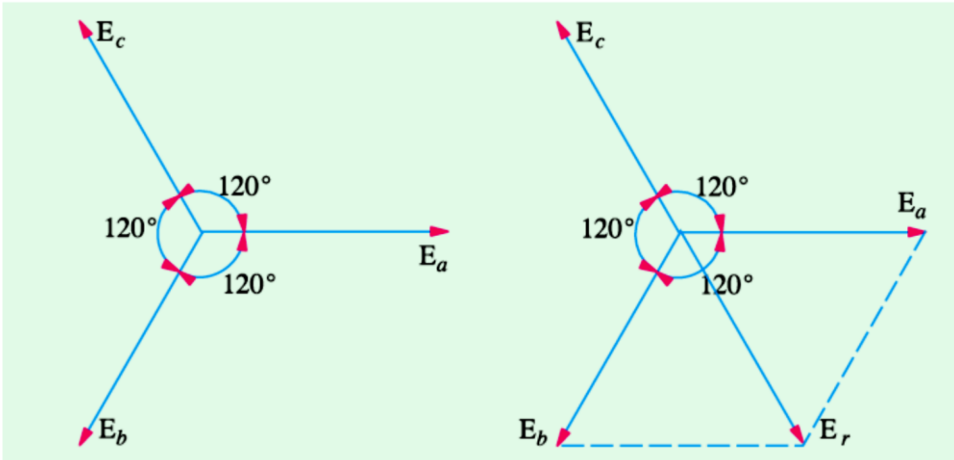

Fig. 4

It can be shown that the sum of the three phase e.m.fs. is zero in the following three ways:

(*i*) The sum of the above three equations **(*i*), (*ii*)** and **(*iii*)** is zero as shown below:

Resultant instantaneous

$$emf = e_a + e_b + e_c$$

$$emf = E_m \sin \omega t + E_m \sin(\omega t - 120) + E_m \sin(\omega t - 240)$$

$$emf = E_m \sin \omega t + 2E_m \sin(\omega t - 180) \cos 60$$

$$emf = E_m \sin \omega t - \frac{2E_m \sin(\omega t)}{2} = 0$$

(*ii*) The sum of ordinates of three e.m.f. curves of Fig. 3 is zero. For example, taking ordinates *AB* and *AC* as positive and *AD* as negative, it can be shown by actual measurement that

AB + *AC* + (– *AD*) = 0

(*iii*) If we add the three vectors of Fig. 4 either vectorially or by calculation, the result is zero.

2. Phase Sequence: -

By phase sequence is meant the order in which the three phases attain their peak or maximum values. In the development of the three-phase e.m.fs. in Fig. 5, clockwise rotation of the field system in Fig. 1 was assumed. This assumption made the e.m.fs. of phase '*b*' lag behind that of '*a*' by 120° and in a similar way, made that of '*c*' lag behind that of '*b*' by 120° (or that of '*a*' by

240°). Hence, the order in which the e.m.fs. of phases *a*, *b* and *c* attain their maximum values is *a b c*. ***It is called the phase order* or *phase sequence*** *a*→*b*→*c* as illustrated in Fig. 5(*a*).

If, now, the rotation of the field structure of Fig. 1 is reversed *i.e.* made anticlockwise, then the order in which the three phases would attain their corresponding maximum voltages would also be reversed. The phase sequence would become *a*→ *b*→*c* . This means that e.m.f. of phase '*c*' would now lag behind that of phase '*a*' by 120° instead of 240° as in the previous case as shown in Fig. 5 (*b*). By repeating the letters, this phase sequence can be written as ***acbacba*** which is the same thing as ***cba***. Obviously, a three-phase system has only two possible sequences : ***abc*** and ***cba*** (*i.e.* ***abc*** read in the reverse direction).

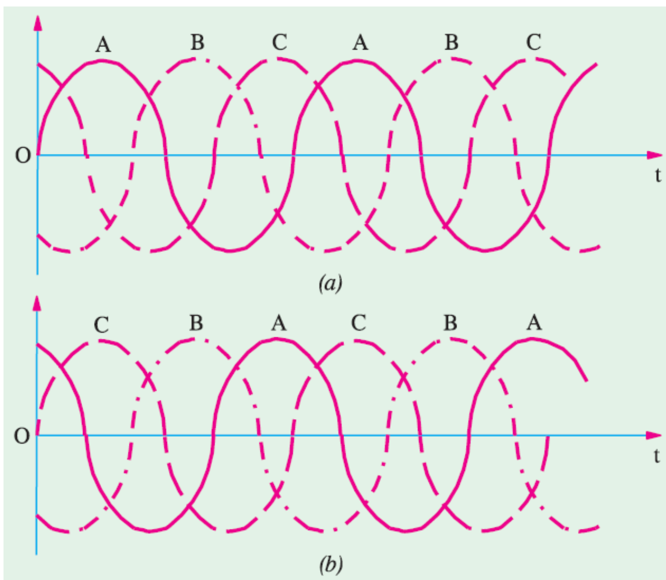

Fig. 5

3. Numbering Phase:

The three phases may be numbered 1, 2, 3 or *a*, *b*, *c* or as is customary, they may be given three colours. The colours used commercially are red, yellow (or sometimes white) and blue. In this case, the sequence is *RYB.*

Obviously, in any three-phase system, there are two possible sequences in which the three coil or phase voltages may pass through their maximum values *i.e.* red → yellow → blue (*RYB*) or red → blue → yellow (*RBY*). By convention, sequence *RYB* is taken as positive and *RBY* as negative.