Armature Winding Of Synchronous Generator

Armature winding of alternators is different from that of d.c. machines. Basically three phase alternators carry three sets of windings arranged in the slots in such a way that there exists a phase difference of 120_o between the induced e.m.f.s. in them. In a d.c. machine, winding is brought out. In three phase alternators winding is open i.e. two ends of each of set of winding is brought out. In three phase alternators, the six terminals are brought out which are finally connected in star or delta and then the three terminals are brought out. Each set of windings represents winding per phase and induced e.m.f. in each set is called induced e.m.f. per phase denoted as E_{ph}. All the coils used for one phase must be connected in such a way that their e.m.f.s. help each other. And overall design should be in such a way that the waveform of an induced e.m.f. is almost sinusoidal in nature.

Winding Terminology

1. **Conductor** : The part of the wire, which is under the influence of the magnetic field and responsible for the induced e.m.f. is called active length of the conductor. The conductor are placed in the armature slots.
2. **Turn** : A conductor in one slot, when connected to a conductor in another slot forms a turn. So two conductors constitute a turn. This is shown in the Figure.1.8

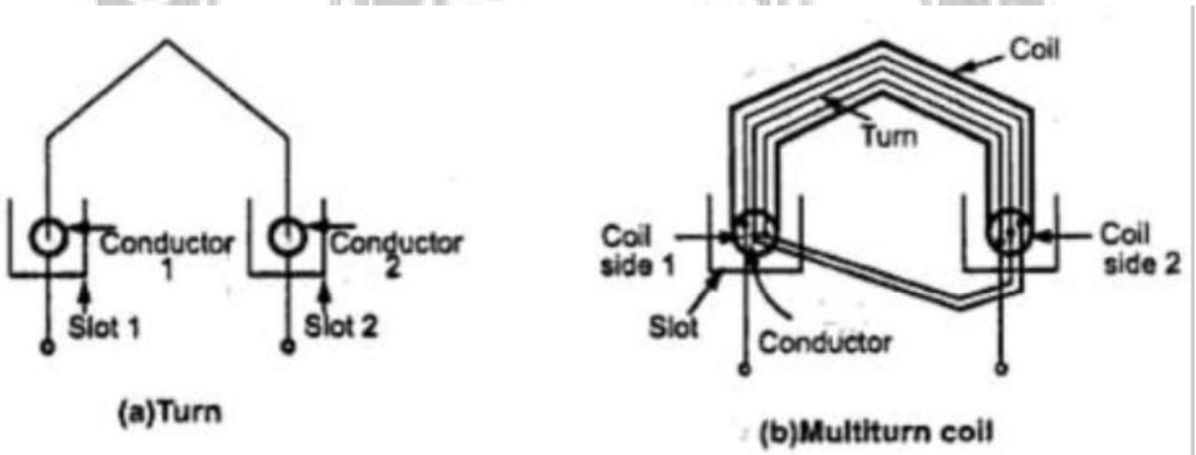

Figure 1.8 Single and Multicoil turn

3. **Coil** : As there are number of turns, for simplicity the number of turns are grouped together to form a coil. Such a coil is called multiturn coil. A coil may consists of single turn coil. The Figure1.8. shows a multiturn coil.
4. **Coil side** : Coil consists of many turns. Part of the coil in each slot is called coil side of a coil as shown in the Figure1.8.
5. **Pole Pitch** : It is centre to centre distance between the two adjacent poles. We have seen that for one rotation of the conductors, 2 poles are responsible for 360_oelectrical of e.m.f., 4 poles are responsible for 720_o electrical of e.m.f. and so on. So 1 pole is responsible for 180_o electrical of induced e.m.f.

   Note : So 180_o electrical is also called one pole pitch.

   Practically how many slots are under one pole which are responsible for 180_oelectrical, are measured to specify the pole pitch.

   e.g. Consider 2 pole, 18 slots armature of an alternator. Then under 1 pole there are 18/2 i.e. 9 slots. So pole pitch is 9 slots or 180_o electrical. This means 9 slots are responsible to produced a phase difference of 180 between the e.m.f.s induced in different conductors. This number of slots/poles is denoted as 'n'.

$$\text{Pole pitch} = 180^\circ \text{ electrical}$$

$$= \text{slots per pole (no. of slots/P)} = n$$

6. **Slot angle** (β) : The phase difference contributed by one slot in degrees electrical is called slot angle β.

As slots per pole contributes 180_o electrical which is denoted as 'n', we can write,

1 slot angle = $180_o/n$

$$\beta = \frac{180^\circ}{n}$$

In the above example, $n = 18/2 = 9$, while $\beta = 180_o/n = 20_o$

Note : This means that if we consider an induced e.m.f. in the conductors which are placed in the slots which are adjacent to each other, there will exist a phase difference of β_o in between them. While if e.m.f. induced in the conductors which are placed in slots which are 'n' slots distance away, there will exist a phase difference of 180_oin between them.

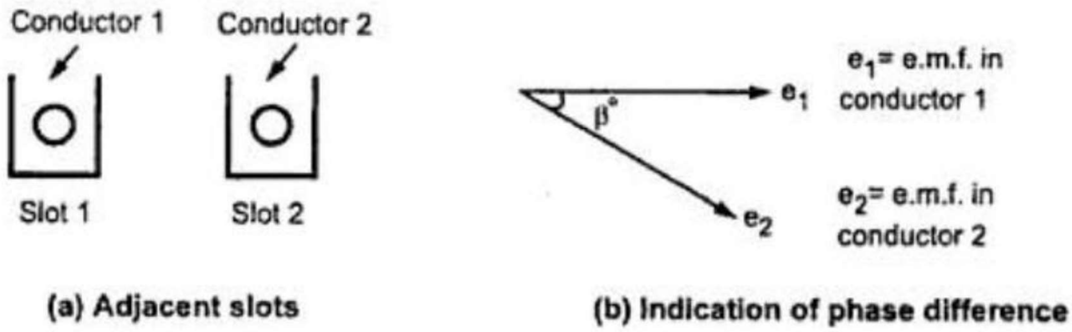

Figure 1.9 Adjacent slots and its angle

Types Of Armature Windings

In general armature winding is classified as,

1) Single layer and double layer winding.
2) Full pitch and short pitch winding.
3) Concentrated and distributed winding.

1. Single Layer and Double Layer Winding

If a slot consists of only one coil side, winding is said to be single layer. This is shown in the Figure 1.10 .While there are two coil sides per slot, one at the bottom and one at the top the winding is called double layer as shown in the Figure1.10

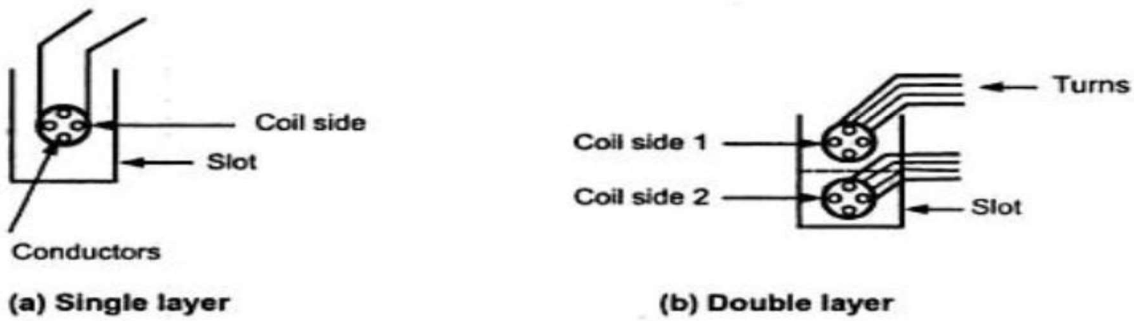

Figure 1.10 single layer and double layer winding

A lot of space gets wasted in single layer hence in practice generally double layer winding is preferred.

2) Full Pitch and Short Pitch Winding

As seen earlier, one pole pitch is electrical. The value of 'n', slots per pole indicates how many slots are contributing electrical phase difference. So if coil side in one slot is connected to a coil side in another slot which is one pole pitch distance away from first slot, the winding is said to be full pitch winding and coil is called full pitch coil. For example, in 2 pole, 18 slots alternator, the pole pitch is n = 18/2 = 9 slots. So if coil side in slot No.1 is connected to coil side No.10 such that two slots No.1 and No.10 are one pole pitch or n slots or 180_o electrical apart, the coil is called full pitch coil. Here we can define one more term related to a coil called coil span.

3. Coil Span

It is the distance on the periphery of the armature between two coil sides of a coil. It is usually expressed interms of number of slots or degrees electrical. So if coil span is 'n' slots or 180_o electrical the coil is called full pitch

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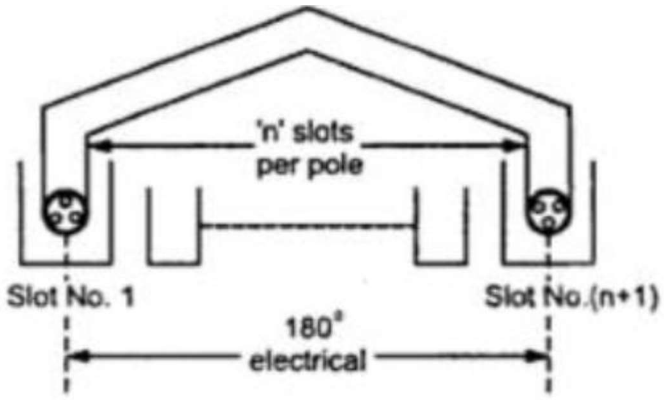

Figure 1.11 full pitched winding

As against this if coils are is slightly less than a pole pitch i.e. less than 180 electrical, the coils are called, short pitched coils or fractional pitched coils. Generally coils are shorted by one or two slots. So in 18 slots, 2 pole alternator instead of connecting a coil side in slot No. 1 to slot No.10, it is connected to a coil side in slot No.9 or slot No. 8, coil is said to be short pitched coil and winding is called short pitch winding. This is shown in Figure1.12

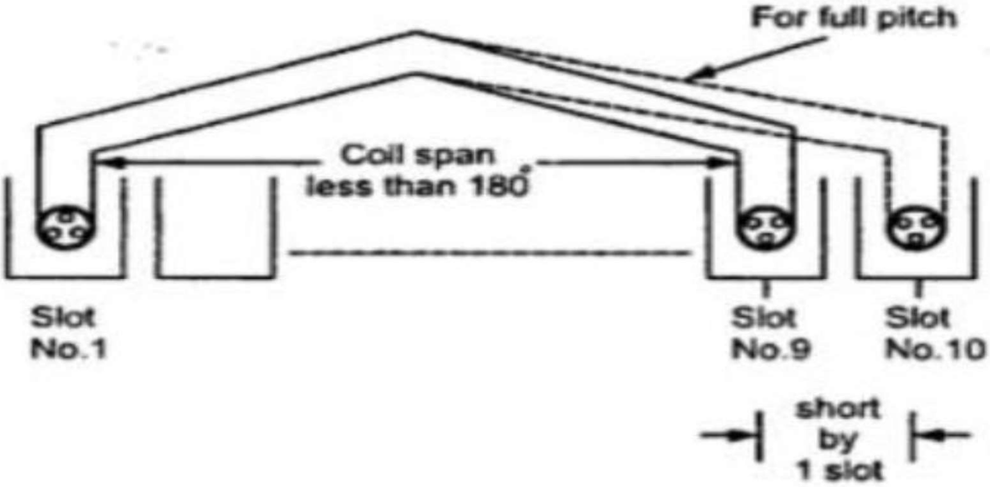

Figure 1.12 short pitched winding

Advantages of Short Pitch Coils

In actual practice, short pitch coils are used as it has following advantages,

1) The length required for the end connections of coils is less i.e. inactive length of winding is less. So less copper is required. Hence economical
2) 2) Short pitching eliminates high frequency harmonics which distort the sinusoidal nature of e.m.f. Hence waveform of an induced e.m.f. is more sinusoidal due to short pitching.
3) As high frequency harmonics get eliminated, eddy current and hysteresis losses which depend on frequency also get minimised. This increases the efficiency.