1.4 Design of Armature Windings

The different armature coils in a d.c. armature Winding must be connected in series with each other by means of end connections (back connection and front connection) in a manner so that the generated voltages of the respective coils will aid each other in the production of the terminal e.m.f. of the winding. Two basic methods of making these end connections are:

1. Simplex lap winding
2. Simplex wave winding

1. Simplex lap winding.

For a simplex lap winding, the commutator pitch $Y_C = 1$ and coil span $Y_S \simeq$ pole pitch. Thus the ends of any coil are brought out to adjacent commutator segments and the result of this method of connection is that all the coils of the armature .ire in sequence with the last coil connected to the first coil. Consequently, closed circuit winding results. This is illustrated in Fig. (1.21) where a part of the lap winding is shown. Only two coils are shown for simplicity. The name lap comes from the way in which successive coils overlap the preceding one.

2. Simplex wave winding

For a simplex wave winding, the commutator pitch $Y_C \simeq 2$ pole pitches and coil span = pole pitch. The result is that the coils under consecutive pole pairs will be joined together in series thereby adding together their e.m.f.s [See Fig. 1.22]. After passing once around the armature, the winding falls in a slot to the left or right of the starting point and thus connecting up another circuit. Continuing in this way, all the conductors will be connected in a single closed winding. This winding is called wave winding from the appearance (wavy) of the end connections.

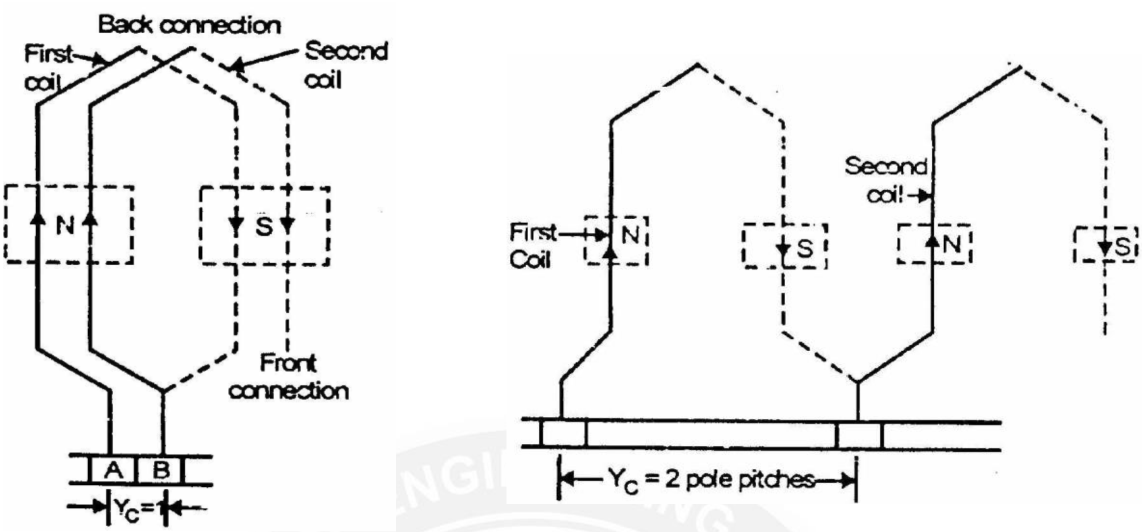

Figure 1.4.1 a) lap winding b) wave winding

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-7.5]

Armature Winding Terminology

Apart from the terms discussed earlier, the following terminology requires discussion:

(i) Back Pitch (Y_B)

It is the distance measured in terms of armature conductors between the two sides of a coil at the back of the armature (See Fig. 1.23). It is denoted by Y_B For example, if a coil is formed by connecting conductor 1 (upper conductor in a slot) to conductor 12 (bottom conductor in another slot) at the back of the armature, then back pitch is Y_B = 12 - 1 = 11 conductors.

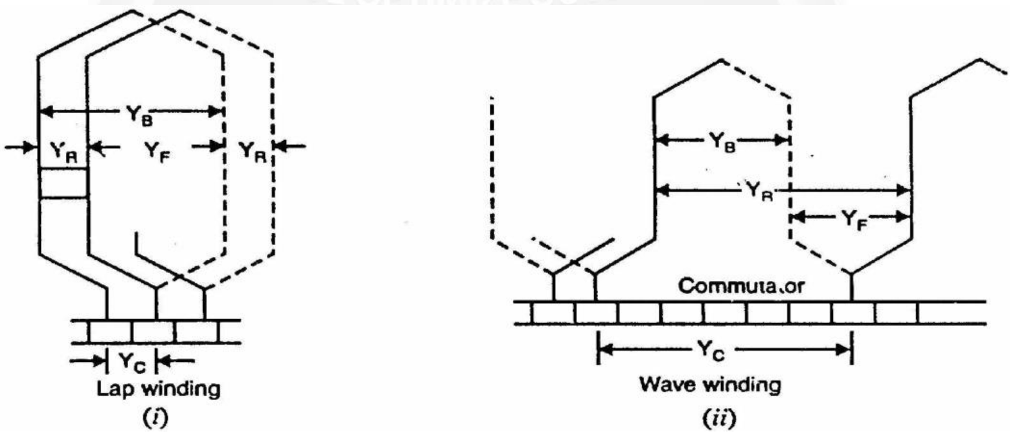

Figure 1.4.2 a) lap winding b) wave winding

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-7.5]

(i) Front Pitch (Y_F)

It is the distance measured in terms of armature conductors between the coil sides attached to any one commutator segment. It is denoted by Y_F For example, if coil side 12 and coil side 3 are connected to the same commutator segment, then front pitch is $Y_F = 12 - 3 = 9$ conductors.

(ii) Resultant Pitch (YR)

It is the distance (measured in terms of armature conductors) between the beginning of one coil and the beginning of the next coil to which it is connected. It is denoted by Y_R. Therefore, the resultant pitch is the algebraic sum of the back and front pitches.

(iii) Commutator Pitch (Y_C)

It is the number of commutator segments spanned by each coil of the armature winding.

For simplex lap winding, $Y_C = 1$

For simplex wave winding, $Y_C \simeq 2$ pole pitches (segments)

(iv) Progressive Winding

A progressive winding is one in which, as one traces through the winding, the connections to the commutator will progress around the machine in the same direction as is being traced along the path of each individual coil. Figure 1.4.3 shows progressive lap winding. Note that $Y_B > Y_F$ and $Y_C = + 1$.

(v) Retrogressive Winding

A retrogressive winding is one in which, as one traces through the winding, the connections to the commutator will progress around the machine in the opposite direction to that which is being traced along the path of each individual coil. Fig. (1.24) (ii) shows retrogressive lap winding. Note that $Y_F > Y_B$ and $Y_C = - 1$. A retrogressive winding is seldom used because it requires more copper.

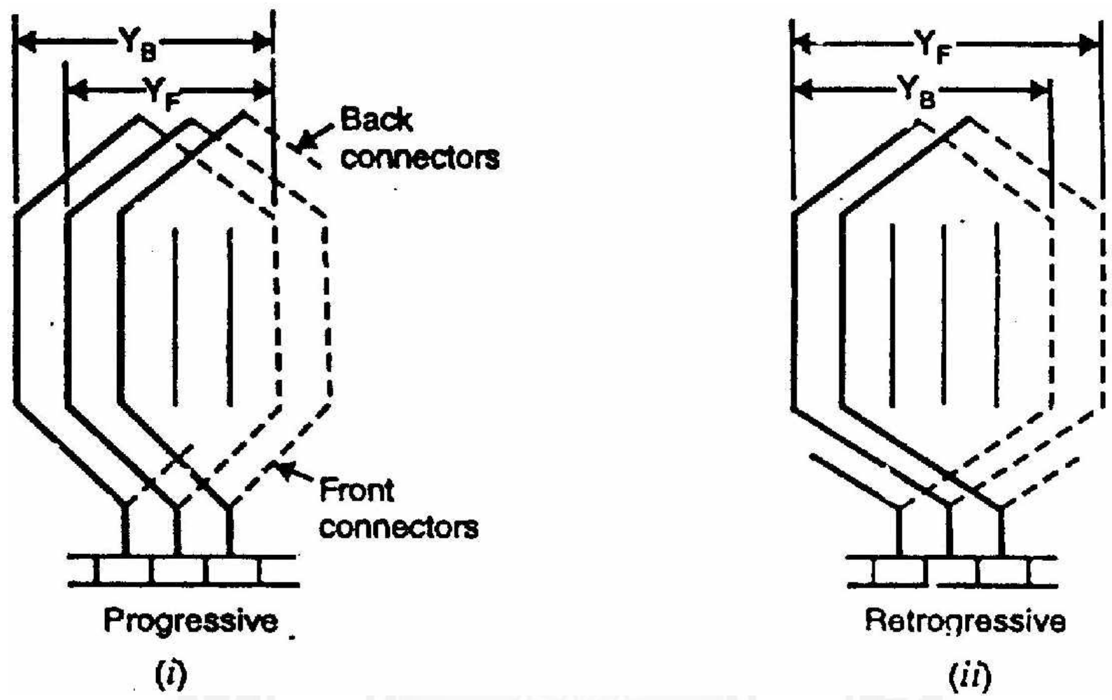

Figure 1.4.3 a) Progressive lap winding b) Retrogressive lap winding

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-7.6]

General Rules For D.C. Armature Windings

In the design of d.c. armature winding (lap or wave), the following rules may be followed:

(i) The back pitch (Y_B) as well as front pitch (Y_F) should be nearly equal to pole pitch. This will result in increased e.m.f. in the coils.

(ii) Both pitches (Y_B and Y_F) should be odd. This will permit all end connections (back as well as front connection) between a conductor at the top of a slot and one at the bottom of a slot.

(iii) The number of commutator segments is equal to the number of slots or coils (or half the number of conductors).

No. of commutator segments = No. of slots = No. of coils

It is because each coil has two ends and two coil connections are joined at each commutator segment

(iv) The winding must close upon itself i.e. it should be a closed circuit winding.

Relations between Pitches for Simplex Lap Winding

In a simplex lap winding, the various pitches should have the following relation:

(i) The back and front pitches are odd and are of opposite signs. They differ numerically by 2,

$Y_B = Y_B = Y_F \pm 2$

$Y_B = Y_F + 2$ for progressive winding

$Y_B = Y_F - 2$ for retrogressive winding

(ii) Both Y_B and Y_F should be nearly equal to pole pitch.

(iii) Average pitch $=(Y_B + Y_F)/2$. It equals pole pitch (= Z/P).

(iv) Commutator pitch, $Y_C = \pm 1$

$Y_C = +1$ for progressive winding

$Y_C = -1$ for retrogressive winding

(v) The resultant pitch (Y_B) is even, being the arithmetical difference of two odd numbers viz., Y_B and Y_F.

Developed diagram

Developed diagram is obtained by imagining the cylindrical surface of the armature to be cut by an axial plane and then flattened out. (i) shows the developed diagram of the winding. Note that full lines represent the top coil sides (or conductors) and dotted lines represent the bottom coil sides (or conductors).

The winding goes from commutator segment 1 by conductor 1 across the back to conductor 12 and at the front to commutator segment 2, thus forming a coil. Then from commutator segment 2, through conductors 3 and 14 back to commutator segment 3 and so on till the winding returns to commutator segment 1 after using all the 40 conductors.

Position and number of brushes

We now turn to find the position and the number of brushes required. The brushes, like field poles, remain fixed in space as the commutator and winding revolve. It is very important that brushes are in correct position relative to the field poles. The arrowhead marked “rotation” in Fig. (1.25) (i) shows the direction of motion of the conductors. By right-hand rule, the direction of e.m.f. in each conductor will be as shown.

In order to find the position of brushes, the ring diagram shown in Fig. (1.25) (ii) is quite helpful. A positive brush will be placed on that commutator segment where the currents in the coils are meeting to flow out of the segment. A negative brush will be placed on that commutator segment where the currents in the coils are meeting to flow in. Referring to Fig. (1.25) (i), there are four brushes—two positive and two negative. Therefore, we arrive at a very important conclusion that in a simplex lap winding, the number of brushes is equal to the number of poles. If the brushes of the same polarity are connected together, then all the armature conductors are connected in four parallel paths; each path containing an equal number of conductors in series.

Since segments 6 and 16 are connected together through positive brushes and segments 11 and 1 are connected together through negative brushes, there are four parallel paths, each containing 10 conductors in series. Therefore, in a simplex lap winding, the number of parallel paths is equal to the number of poles.

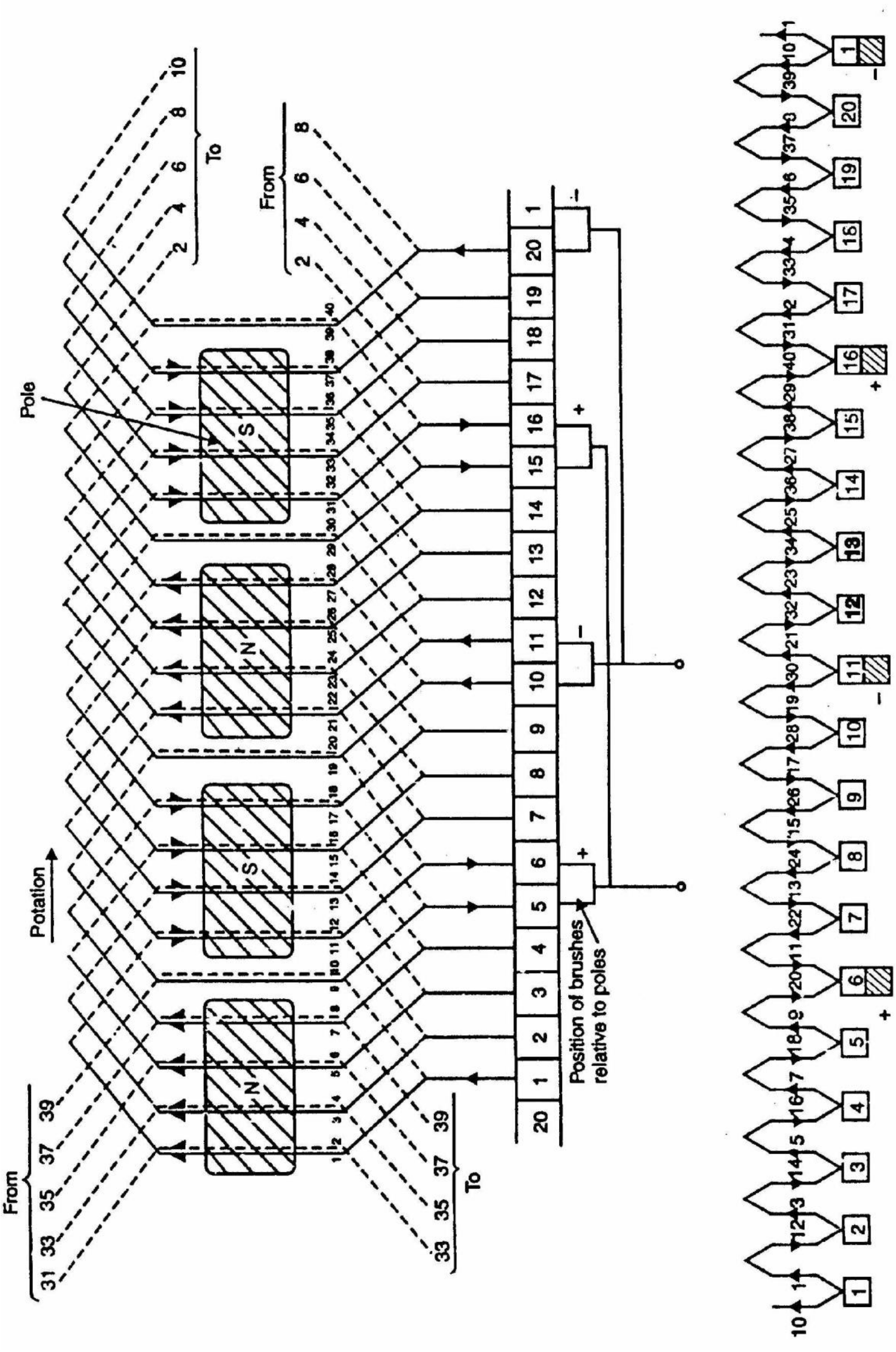

Figure 1.4.4 Sequence diagram for winding

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-7.15]

Simplex Wave Winding

The essential difference between a lap winding and a wave winding is in the commutator connections. In a simplex lap winding, the coils approximately pole pitch apart are connected in series and the commutator pitch $Y_C = \pm 1$ segment. As a result, the coil voltages add. In a simplex wave winding, the coils approximately pole pitch apart are connected in series and the commutator pitch $Y_C \simeq 2$ pole pitches (segments). Thus in a wave winding, successive coils "wave" forward under successive poles instead of "lapping" back on themselves as in the lap winding.

The simplex wave winding must not close after it passes once around the armature but it must connect to a commutator segment adjacent to the first and the next coil must be adjacent to the first as indicated. This is repeated each time around until connections are made to all the commutator segments and all the slots are occupied after which the winding automatically returns to the starting point. If, after passing once around the armature, the winding connects to a segment to the left of the starting point, the winding is retrogressive. If it connects to a segment to the right of the starting point, it is progressive. This type of winding is called wave winding because it passes around the armature in a wave-like form.

Developed diagram

Fig. (1.30) (i) shows the developed diagram for the winding. Note that full lines represent the top coil sides (or conductors) and dotted lines represent the bottom coil sides (or conductors). The two conductors which lie in the same slot are drawn nearer to each other than to those in the other slots.

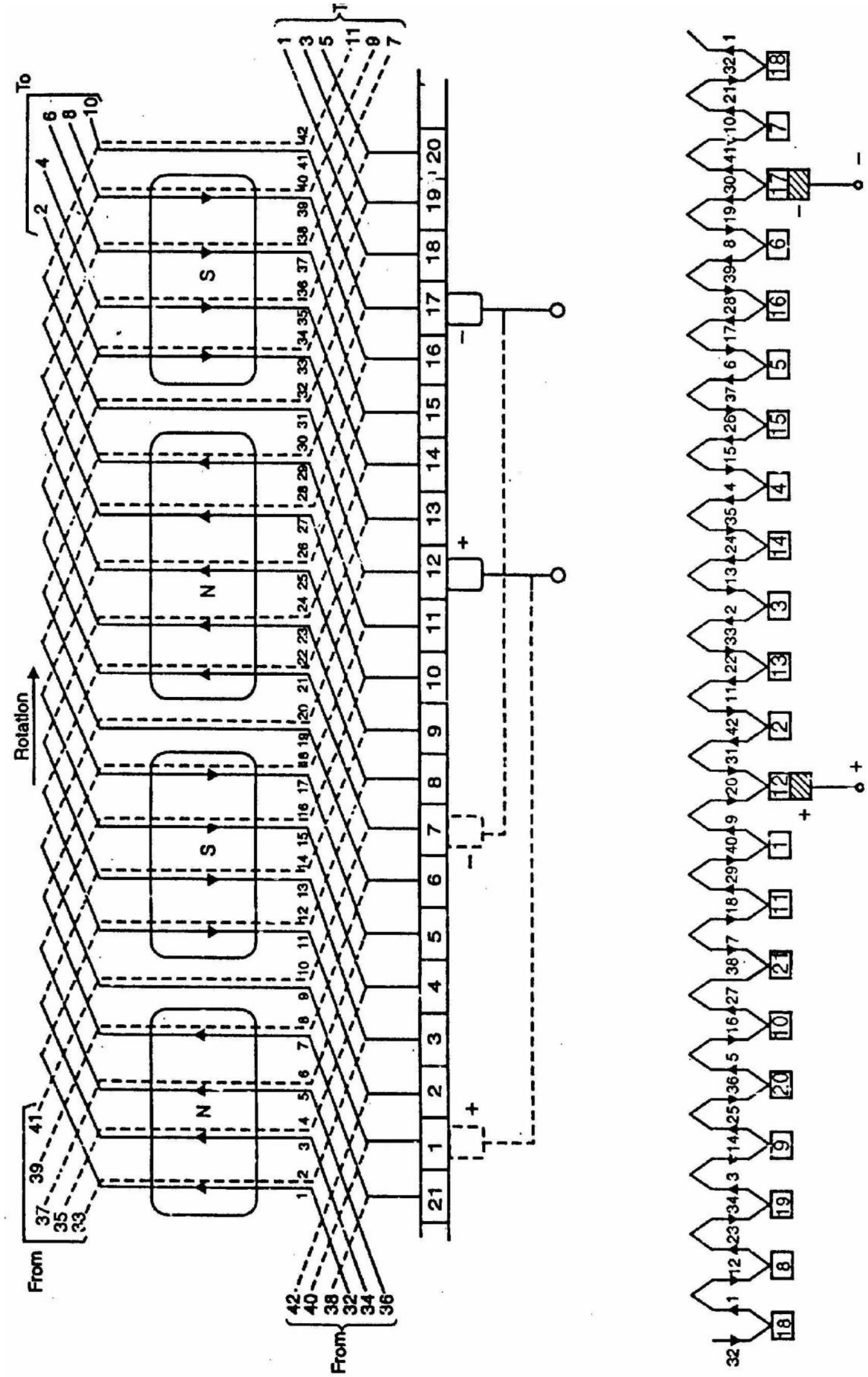

Figure 1.4.5 Sequence diagram for winding

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-7.15]