

## DC Machine Armature Winding (Hadi Saadat)

The DC machine armature windings are always of the closed continuous type of double-layer lap or wave winding. For small machines, the coils are directly wound into the armature slots using automatic winders. In large machines, the coils are preformed and then inserted into the armature slots. Each coil consists of a number of turns of wire, each turn taped and insulated from the other turns and form the rotor slot. Each side of the turn is called a *conductor*. The number of conductors on a machine's armature is given by

$$Z = 2CN_c \quad (1)$$

Where  $Z$  = number of conductors on rotor

$C$  = number of coils on rotor

$N_c$  = number of turns per coil

Since the voltage generated in the conductor under the South Pole opposite the voltage generated in the conductor under the North Pole, the coil span is made equal to 180 electrical degrees, i.e., one pole pitch. In a 2-pole machine 180 electrical degrees is equal to 180 mechanical degrees, whereas in a 4-pole machine 180 electrical degrees is equal to 90 mechanical degrees. In general, the relationship between the electrical angle  $\theta_e$  and mechanical angle  $\theta_m$  is given by

$$\theta_e = \frac{P}{2} \theta_m \quad (2)$$

Where  $P$  is the number of poles?

The most commonly used winding is a two-layer winding. The number of coils for a two-layer winding is equal to the number of armature slots. Thus, each armature slot has two sides of two different coils. In the preformed coils, one side of a coil is placed at the bottom half of a slot and the other side at the top half. If  $S$  is the number of slots in the rotor, the coil pitch is designated by  $y$  is given by

$$y = \text{Integer value of } \left( \frac{S}{P} \right) \quad (3)$$

That is if we place one side of the coil in slot  $m$ , the other side must be inserted in slot  $m + y$ .

The manner in which the coils are connected together will form the type of armature winding.

Let  $E_c$  and  $I_c$  are the voltage and current per coil. If  $a$  is the number of parallel paths between brushes, then the number of series conductor per parallel path between brushes is  $Z/a$ . Hence the average generated emf and the armature current are given by

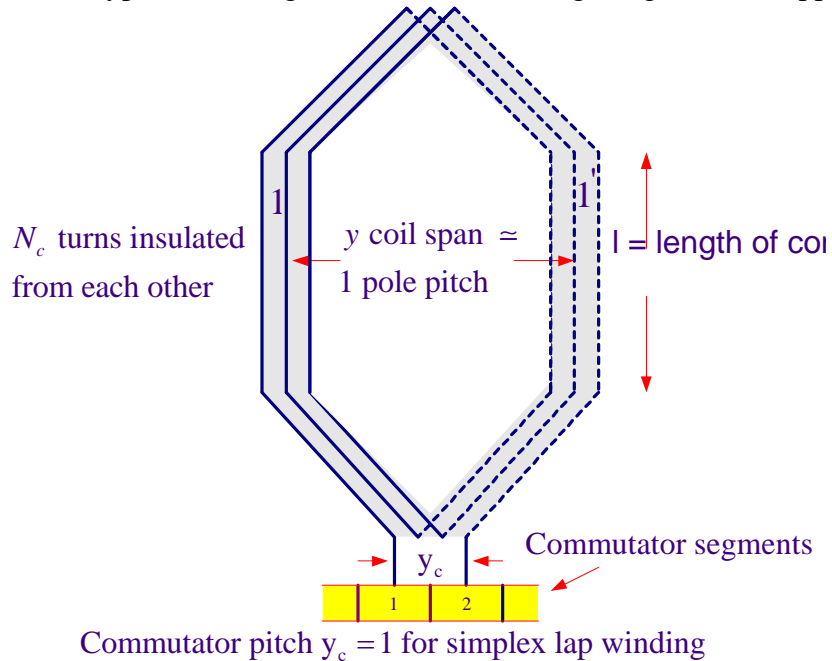
$$\begin{aligned} E &= \frac{Z}{a} E_c \\ I_a &= aI_c \end{aligned} \quad (4)$$

## Simplex Lap Winding

In one type known as the *simplex lap winding* the end of one coil is connected to the beginning of the next coil with the two ends of each coil coming out at adjacent commutator segments. For

a progressive lap winding the commutator pitch  $y_c = 1$ . A typical coil of  $N_c$  turns for a simplex lap winding is shown in Figure 1.

In the simplex lap winding the number of parallel path between brushes is equal to the number of poles, i.e.,  $P = a$ . This type of winding is used for low-voltage, high-current applications.



**Figure 1** A typical coil for lap winding with  $y_c = 1$ .

Let us consider a four-pole, two-layer, simplex lap winding with 8 slots. If number of turns per coil  $N_c = 1$ , the total number of conductors is  $Z = 2(1)(8) = 16$ . From (3) the coil pitch is

$$y = \frac{8}{4} = 2 \text{ slots}$$

Figure 2 (a) shows the winding connection where the two ends of a coil are connected to adjacent commutator segments. The coils in each path are connected in series and the winding close upon itself. The number of parallel path between the brushes and the winding arrangement can be seen more clearly by the developed diagram of the armature as shown in Figure 2(b). In the developed view, the winding is cut along the axial length and is laid flat on the paper.

### Simplex wave winding

As we have seen in the lap winding, the two ends of a coil are connected to adjacent commutator segments ( $y_c = 1$ ). In the wave winding, the two ends of a coil are connected to the commutator segments that are approximately 360 electrical degrees apart (i.e., 2-pole pitch). This way all the coils carrying current in the same direction are connected in series. Therefore, there are only two parallel paths between the brushes, i.e.,  $a = 2$  independent of the number of poles. This type of winding is used for low-current, high-voltage applications.

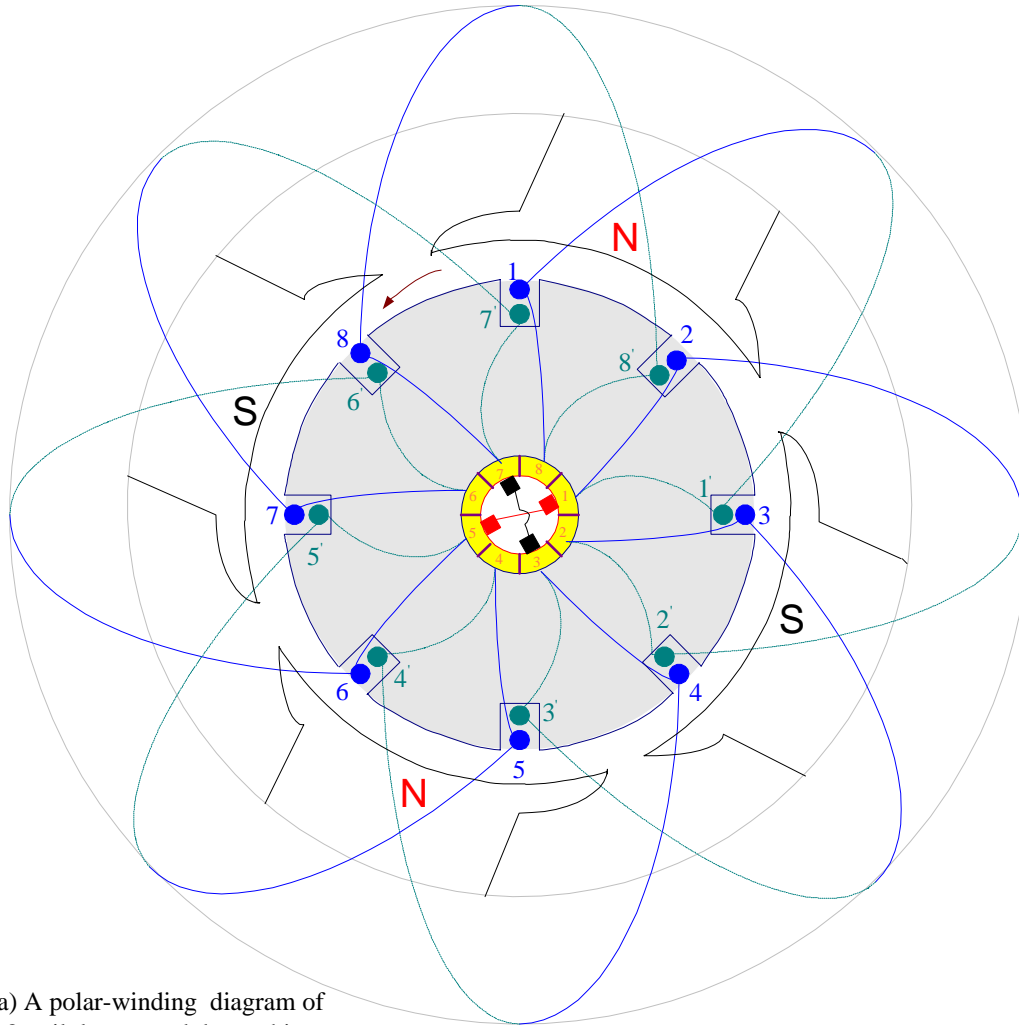


Figure 2(a) A polar-winding diagram of a 4-pole, 8-coil, lap wound dc machine

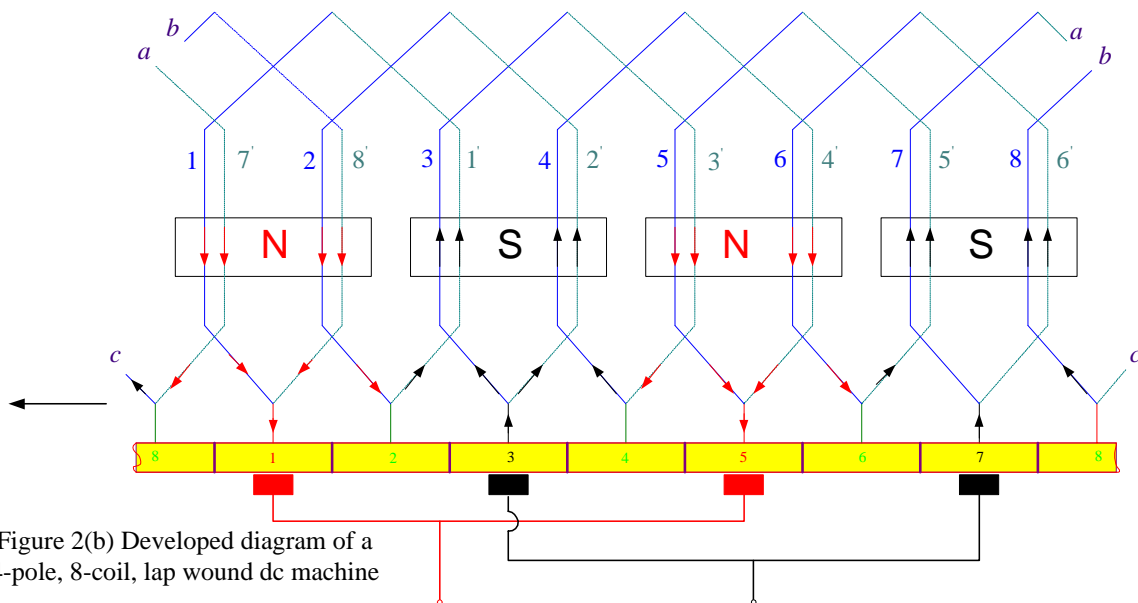


Figure 2(b) Developed diagram of a 4-pole, 8-coil, lap wound dc machine

**To be continued** An example for a simplex wave winding will be included.