Commutation

5.1 Introduction

Consider the circuit shown in Fig. (5-1), which is an ***R-L*** circuit fed by a d-c source through a switch ***S***. When switch ***S*** closed to position ***ON***. The current will increase in the circuit until it reaches the value ($I = E/R$), because there is no reactance for ***L*** since the frequency = zero.

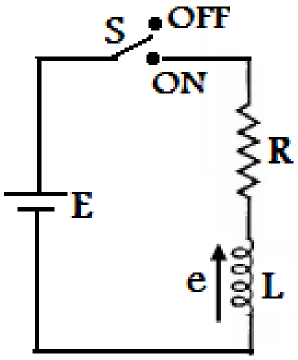

Fig. (5-1)

When the switch ***S*** closed the current will increase gradually because the inductance during the transient period will generates an emf against the flow of current (the source voltage) due to Lenze's law and this $\text{emf} = -N\frac{d\phi}{dt}$ due to Faradays Law.

Hence the transient current will be as shown in Fig. (5-2).

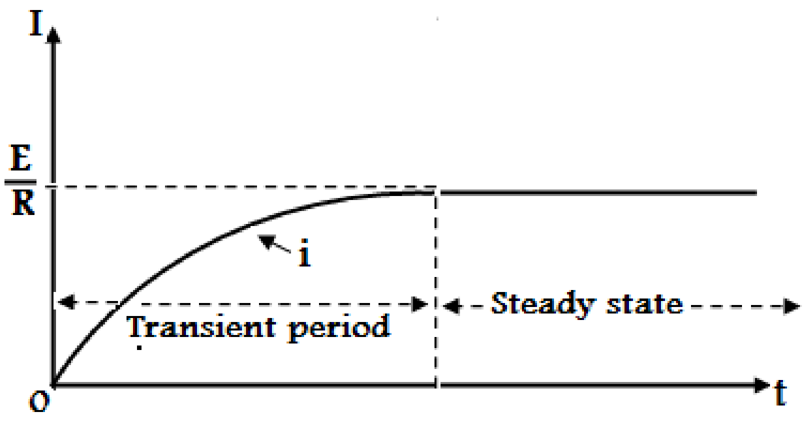

Fig. (5-2)

It is clear that $\frac{di}{dt}$ at t = 0 have maximum value and so is $\frac{d\phi}{dt}$.

Then this value decreased gradually until it reaches the zero value at steady-state.

When switch ***S*** opened to the ***OFF*** position, the current will start to decrease from its steady state value to the zero value during a very short period (the period of disconnection between the switch parts) measured in nano seconds i.e. (10^{-9} sec). During this period, and since the current decreasing through the inductance, it will induce an emf in the direction of current flow (the source voltage) due to Lenze's Law. It's value due to Faraday's Law $= -N\frac{d\phi}{dt}$.

The problem in opening this circuit is the ($\frac{d\phi}{dt}$) value which is very high due to the small value of the switching time, as will be shown in the following example.

Let Φ =0.025 mWb

T = $25x10^{-9}$

N =20 turn

$$\therefore \quad E = (-20)\left(-\frac{25\times10^{-6}}{25\times10^{-9}}\right) = 20 \quad KV$$

Now, imagine the difference in voltage between the moving contact of the switch and the circuit terminal is (20kv) and the break down voltage of the dry air is 30kv/cm or 3Mv/m. hence, a spark will arises between the switch terminals due to the ionization of the air-gap.

This way of high voltage generation is widely used in industrial applications, for example, the high voltages of television screen, or in spark plug in cars machine ….. etc.

5.2 Commutation Problem

A problem arises in d-c machines during loading only, that, a spark generates between the trailing edge of brushes and the commutator segment behind. This spark generates a high temperature in commutator region leads to damage the commutator and brush, and if the spark is very high sometimes leads to a short circuit between brushes, also, it cause a very high noise in the communication equipments near to it. So, it is a serious problem and should be solved. To solve this problem, one should know the reason of this spark.

From the function of the commutator, it is expected that the coil in contact to the brushes, will be subjected to change in the direction of current flows through it, as will be explained with the aid of Fig. (5-3) and Fig.(5-4a, b, c) which show the ideal case of commutation by considering coil B which is the coil under commutation.

Fig. (5-3)

In Fig.(5-4a) The current in coil B is from left to right, while that in Fig. (5-4c) Flowing from right to left. The value of this current in a two-pole lap connected armature is (*I/2*), so the current in coil ***B*** changes from (*I/2*) to – *I/2* as shown in Fig. (5-5) during the time elapsed to pass one commutator segment under the brush denoted by (***T***). The bold line in the figure represents the ideal case at which at time ***T/2*** the current in coil B reaches zero while it reaches the value ***I/2*** at time T, which is the case of no sparking during commutation. What happens really is that when the current decreases in coil B between time (0) and (***T/2***) as shown in figure the coil will induce an emf in the same polarity as that of the source (i.e from left to right) in order to increase the decayed current, while after (***T/2***) the coil generates emf against the source voltage or against the direction of the increased current (i.e from left to right also). These induced voltage against the decrease and the increase of the current through coil B leads to delay the change of current as shown in the dashed line or curve such that, the current will never reaches ***-I/2*** at time ***T***, so this current will be chopped during a very small time. This case will be similar to that discussed in (5-1) in generating a high voltage between the trailing edge and the leaving commutator segment causes to pass the comuutation current in air-gap.

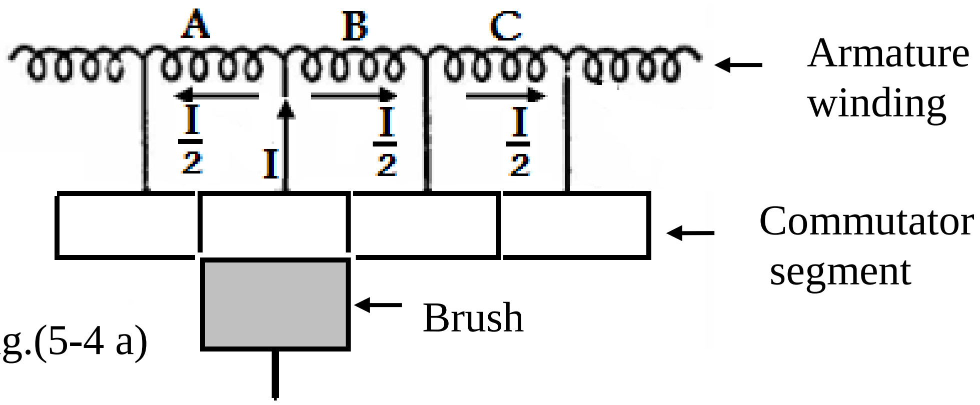

Fig.(5-4 a)

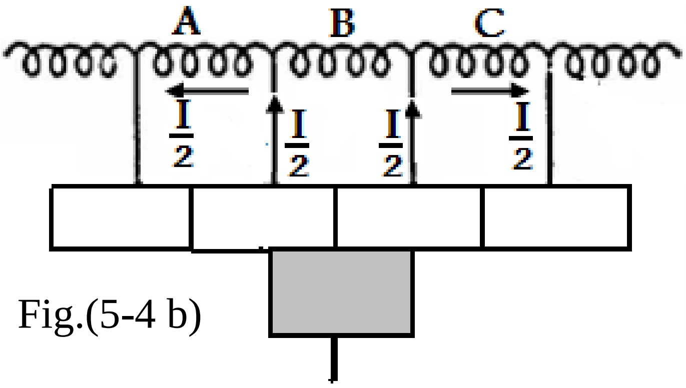

Fig.(5-4 b)

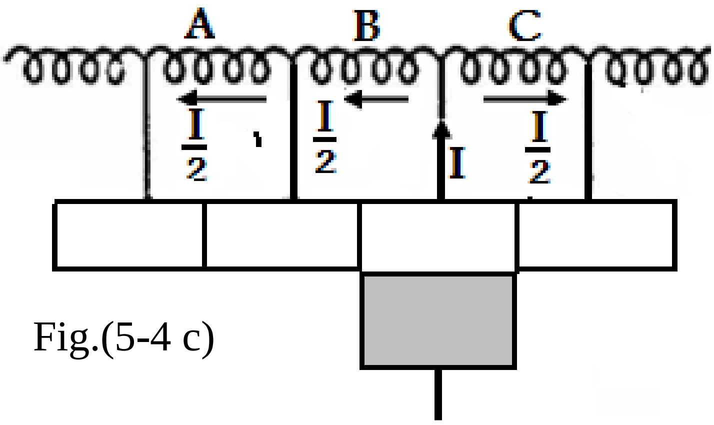

Fig.(5-4 c)

Fig.(5-4)

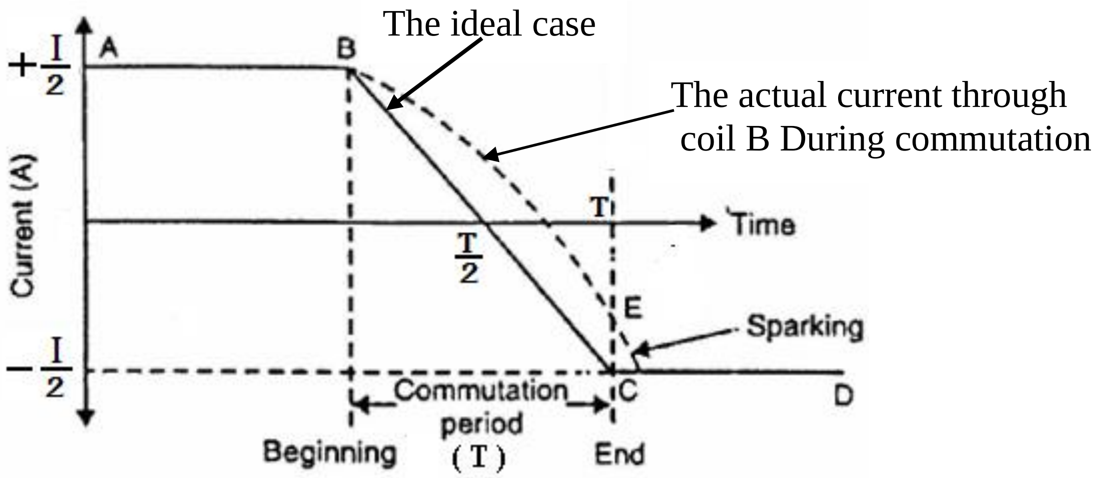

Fig.(5-5

5.3 Solution of Commutation Problem

From the analysis of the spark reason it is clear that if ***T*** increased the commutation current will be reduced. This can be achieved by increasing the brush width, but as shown previously (the short-circuit conductors will be increased during operation). The designer will have to compromise between these two problems. In small machines, and since the armature current is relatively small, a brush width of about 1.5 commutator segment will be expected, while in medium and large machines the inter-poles or (commutating pole – compole -) are considered to eliminate the induced voltage in the coil under commutation (coil B in Fig. (5-4)) by generating a motional emf against it and equal to its value leads to make the commutation ideal (the bold line in Fig. (5-5)). For that reason the interpole position is on the G.N.A and will be narrow in order to effect on the coil under commutation only. It is short, in order, not to increase the armature reaction (discussed in chapter 4).