Outcome

By the end of the lesson, the student will be able to

1.**define armature reaction** and **identify its two main effects** (demagnetizing and cross-magnetizing) with at least **90% accuracy**.

2. explain the concept of Magnetic Neutral Axis (M.N.A.) and how its position changes under load conditions, using correct technical terminology.

3. calculate demagnetizing ampere-turns per pole and **cross-magnetizing ampere-turns per pole** for a given DC generator when provided with numerical data (Z, Ia, P, θ).

4. analyze the effect of brush lead angle on the performance of the generator and determine whether the armature reaction increases distortion, demagnetization, or both

Armature Reaction

By armature reaction is meant the effect of magnetic field set up by armature current on the distribution of flux under main poles of a generator. The armature magnetic field has two effects:

(i) It demagnetizes or weakens the main flux.

(ii) It cross-magnetizes or distorts it.

The first effect leads to reduced generated voltage and **the second** to the sparking at the brushes. These effects are well illustrated in Fig.1 which shows the flux distribution of a bipolar generator when there is no current in the armature conductors. It is seen that:

(a) The flux is distributed symmetrically with respect to the polar axis, which is the line joining the centers of NS poles.

(b) The magnetic neutral axis or plane (M.N.A.) coincides with the geometrical neutral axis or plane (G.N.A.).

Magnetic neutral axis (M.N.A) may be defined as the axis along which no e.m.f. is produced in the armature conductors because they then move parallel to the lines of flux. Or M.N.A. is the axis which is perpendicular to the flux passing through the armature. Brushes are always placed along M.N.A. Hence, M.N.A. is also called 'axis of commutation' because reversal of current in armature conductors takes place across this axis. In Fig.1 is shown vector OFm which represents, both in magnitude and direction, the m.m.f. producing the main flux and also M.N.A. which is perpendicular to OFm.

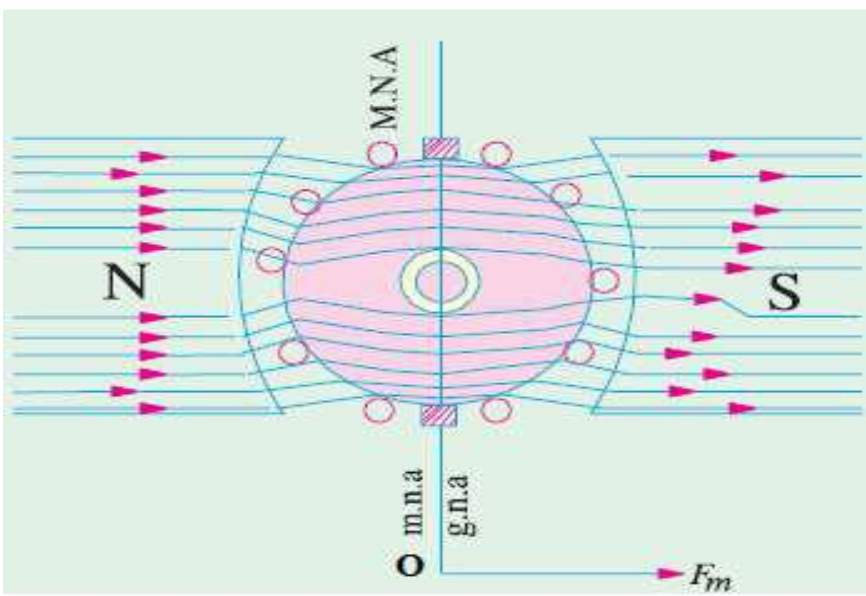

Figure 1

In Fig. 2 is shown the field (or flux) set up by the armature conductors alone when carrying current, the field coils being unexcited. As shown in Fig.2, the m.m.fs. of the armature conductors combine to send flux downwards through the armature. The armature m.m.f. (depending on the strength of the armature current) is shown separately both in magnitude and direction by the vector OFA which is parallel to the brush axis.

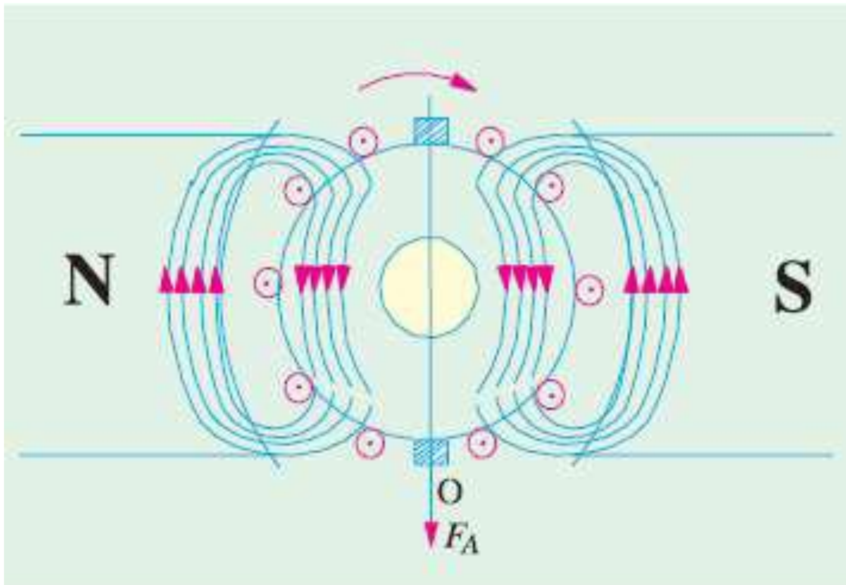

Figure 2

So far, we considered the main m.m.f. and armature m.m.f. separately as if they existed independently, which is not the case in practice. Under actual load conditions, the two exist simultaneously in the generator as shown in Fig.3

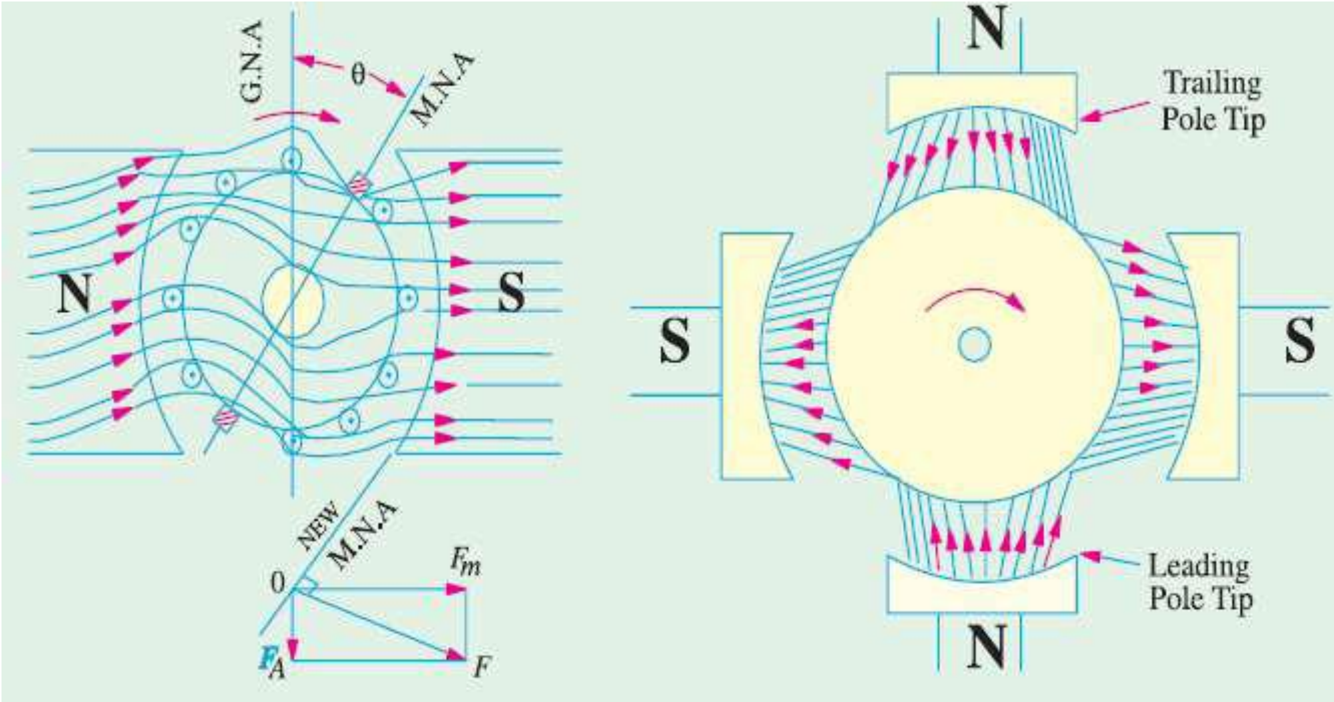

Figure 3

It is seen that the flux through the armature is no longer uniform and symmetrical about the pole axis, rather it has been distorted. The flux is seen to be crowded at the trailing pole tips but weakened or thinned out at the leading pole tips (the pole tip which is first met during rotation by armature conductors is known as the leading pole tip and the other as trailing pole tip).

2- Demagnetizing and Cross-magnetizing Conductors

The exact conductors which produce these distorting and demagnetizing effects are shown in Fig. 4 where the brush axis has been given a forward lead of θ so as to lie along the new position of M.N.A. All conductors lying within angles AOC = BOD = 2θ at the top and bottom of the armature, are carrying current in such a direction as to send the flux through the armature from right to left

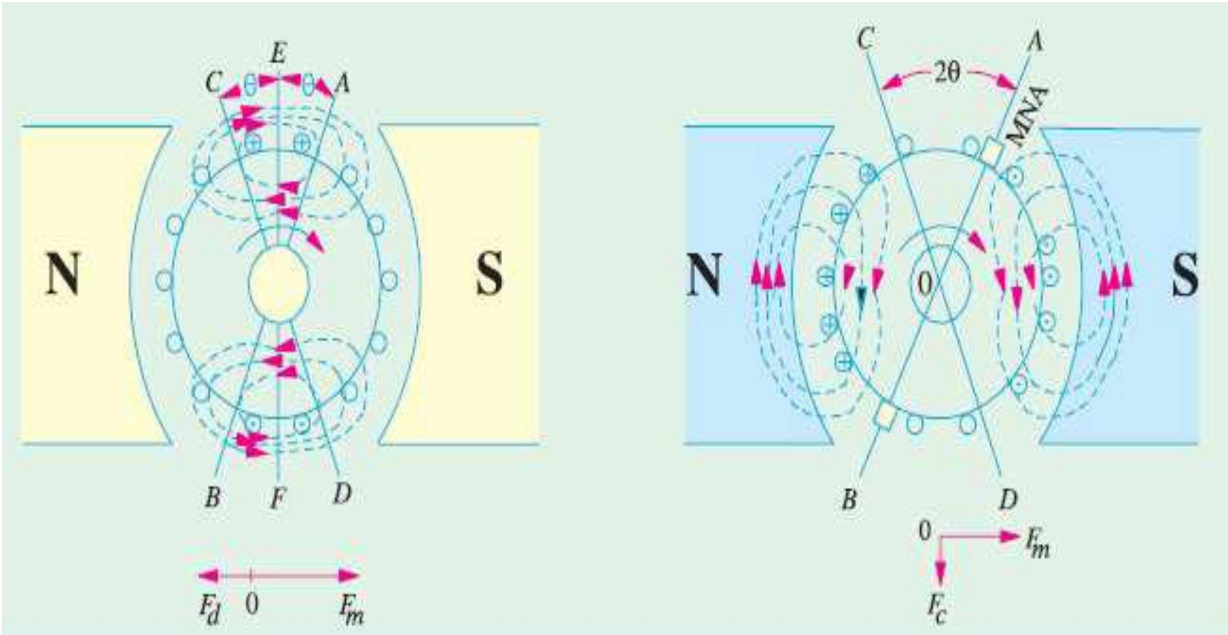

Figure 4

Now consider the remaining armature conductors lying between angles AOD and COB. As shown in Fig. 4, these conductors carry current in such a direction as to produce a combined flux pointing vertically downwards i.e. at right angles to the main flux. This results in distortion of the main field. Hence, these conductors are known as cross-magnetizing conductors and constitute distorting ampere conductors.

3- Demagnetizing AT per Pole

Since armature demagnetizing ampere-turns are neutralized by adding extra ampere-turns to the main field winding, it is essential to calculate their number.

But before proceeding further, it should be remembered that the number of turns is equal to half the number of conductors because two conductors-constitute one turn.

Let **Z = total number of armature conductor**

I = Current in Armature Conductor

= I_a / 2 … for simplex wave winding

= I_a / p … for simplex lab winding

θ_m = forward lead in mechanical or geometrical or angular degree

Total number of conductors in angles AOC and BOD is $\frac{4\theta_m}{360} * Z$

As two conductor constitute one turn

:- total number of turns in these angles = $\frac{2\theta_m}{360} * Z\ I$

:- demagnetizing amp – turn per pair of poles = $2\,\frac{\theta_m}{360} * Z\ I$

:- Demagnetising amp – turn / pole = $\frac{\theta_m}{360} * Z\ I$:- AT_dPer pole = $\frac{\theta_m}{360} * Z\ I$

4- Cross-magnetizing AT per pole

The conductors lying between angles AOD and BOC constitute what are known as distorting or cross-magnetizing conductors. Their number is found as under:

total armature – conductor / pole both cross and demagnetizing= Z/ P

demagnetizing conductor / pole = $\frac{2\theta_m}{360} * Z$ Found Above

cross- demagnetizing conductor / pole = $\frac{z}{p} - z\,\frac{2\theta_m}{360}$ =$Z\left(\frac{1}{p} - \frac{2\theta_m}{360}\right)$

cross- demagnetizing amp- conductor / pole =$Z\ I\left(\frac{1}{p} - \frac{2\theta_m}{360}\right)$

cross- demagnetizing amp turn / pole = $Z\ I\left(\frac{1}{2p} - \frac{\theta_m}{360}\right)$

(remembering that two conductors make on turn)

AT_C/ Pole = $Z\ I\left(\frac{1}{2p} - \frac{\theta_m}{360}\right)$

Note 1. For neutralizing the demagnetizing effect of armature-reaction, an extra number of turns may be put on each pole:

No. of extra turns/pole = $\boldsymbol{AT_d}$ / $\boldsymbol{I_{sh}}$ –for shunt generator

No. of extra turns/pole =$\boldsymbol{AT_d}$ /$\boldsymbol{I_a}$ - for series generator

Note 2. If lead angle is given in **electrical degrees**, it should be **converted** into **mechanical** degrees by the following relation:**θm = 2θe / P**

5- Compensating Windings

These are used for large direct current machines which are subjected to large fluctuations in load i.e. rolling mill motors and turbo-generators etc. Their function is to neutralize the cross magnetizing effect of armature reaction. In the absence of compensating windings, the flux will be suddenly shifting backward and forward with every change in load. This shifting of flux will induce statically induced e.m.f. in the armature coils. The magnitude of this e.m.f. will depend upon the rapidity of changes in load and the amount of change. It may be so high as to strike an arc between the consecutive commutator segments across the top of the mica sheets separating them. This may further develop into a flashover around the whole commutator thereby short-circuiting the whole armature. These windings are embedded in slots in the pole shoes and are connected in series with armature in such a way that the current in them flows in opposite direction to that flowing in armature conductors directly below the pole shoes. An elementary scheme of compensating winding is shown in Fig. 5. It should be carefully noted that compensating winding must provide sufficient m.m.f so as to counterbalance the armature m.m.f. Let

Z_C = No. of compensating conductors/pole face

Z_a = No. of active armature conductors/pole,

I_a= Total armature current

I_a/A = current/armature conductor

$\therefore Z_C * I_a$= Za (Ia/A) or Zc = Za/A

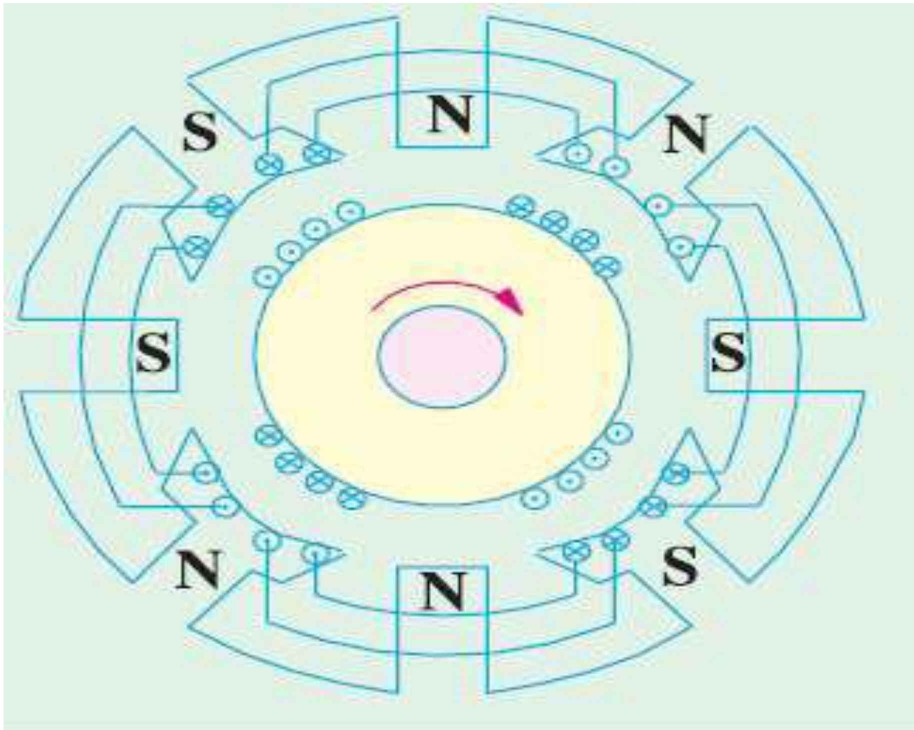

Figure 5

6- No. of Compensating Windings

No. of armature conductors/pole = Z / P

No. of armature turns/pole = Z / 2P

No. of *armature-turns* immediately under one pole = $\frac{Z}{2P} * \frac{Pole\ Arc}{Pole\ pitch}$

No. of *armature amp-turns/pole* for compensating winding = $0.7 \times \frac{Z\ I}{2P}$

Example 1. A **4-pole** generator has a wave-wound armature with **722 conductors**, and it delivers **100 A** on full load. If the brush lead is **8°**, calculate the armature demagnetising and cross-magnetizing ampere turns per pole.

Solution: $I = I_a/2 = 100/2 = 50\text{A};\ Z = 722;\ \theta_m = 8°$

$$AT_d/\text{pole} = ZI.\frac{\theta_m}{360} = 722 \times 50 \times \frac{8}{360} = 802$$

$$AT_c/\text{pole} = ZI.\left(\frac{1}{2P} - \frac{\theta_m}{360}\right)$$

$$= 722 \times 50\left(\frac{1}{2 \times 4} - \frac{8}{360}\right) = 37/8$$

Example 2. An **8-pole** generator has an output of **200 A** at **500 V**, the **lap connected** armature has **1280 conductors, 160 commutator segments**. If the brushes are advanced **4-segments** from the no-load neutral axis, estimate the armature demagnetizing and cross-magnetizing ampere-turns per pole.

Solution $I = 200/8 = 25\text{ A},\ Z = 1280,\ \theta_m = 4 \times 360/160 = 9°;\ P = 8$

$$AT_d/\text{pole} = ZI\theta_m/360 = 1280 \times 25 \times 9/360 = \mathbf{800}$$

$$AT_c/\text{pole} = ZI\left(\frac{1}{2p} - \frac{\theta_m}{360}\right) = 1280 \times 25\left(\frac{1}{2 \times 8} - \frac{9}{360}\right) = \mathbf{1200}$$

Example 3. A **4-pole wave-wound** motor armature has **880 conductors** and delivers **120 A**. The brushes have been displaced through **3 angular degrees** from the geometrical axis. Calculate

(a) demagnetizing amp-turns/pole

(b) cross magnetizing amp-turns/pole

(c) the additional field current for neutralizing the demagnetization of the field winding has **1100 turns/pole**.

Solution: $Z = 880;\ I = 120/2 = 60\text{ A};\ \theta = 3°$ angular

(a) $\therefore\ AT_d = 880 \times 60 \times \frac{3}{360} =$ **440 AT**

(b) $\therefore\ AT_c = 880 \times 60\left(\frac{1}{8} - \frac{3}{360}\right) = 880 \times \frac{7}{60} \times 60 =$ **6160**

or Total AT/pole = $440 \times 60/4 = 6600$

Hence. AT_c/pole = Total AT/pole − AT_d/ pole = 6600 − 440 = 6160

(c) Additional field current = 440/1100 = **0.4 A**

Home work

A 6-pole wave-wound DC generator has **900 armature conductors** and delivers **80 A** under full load. If the brushes are given a **mechanical lead of 6°**, calculate:

1. The **demagnetizing ampere-turns per pole**.
2. The **cross-magnetizing ampere-turns per pole**.

An 8-pole lap-wound generator has **1200 armature conductors** and carries an armature current of **150 A**. The brushes are shifted by **5 electrical degrees**. Calculate:

1. The **mechanical lead angle**.
2. The **demagnetizing ampere-turns per pole**.
3. The **cross-magnetizing ampere-turns per pole**