SRIMAAN COACHING CENTRE-TRICHY-TNPSC-CESE-ASSISTANT ENGINEER(A.E)-TANGEDCO (TNEB)-EEE-UNIT-V-STUDY MATERIAL-TO CONTACT:8072230063.

2023-24
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ASSISTANT ENGINEER (A.E)

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EEE

UNIT-V-ELECTRICAL MACHINES

(NEW SYLLABUS 2023-24)

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2023-24 SRIMAAN

TNPSC-Combined Engineering Services Examination (CESE)

ASSISTANT ENGINEER (AE)-EEE-TANGEDCO-(TNEB)

UNIT-V-ELECTRICAL MACHINES

D.C. Machines:

A D.C generator as shown in figure below the armature be driven by a prime mover in the clock wise direction and the stator field is excited to produce the field poles as shown. There will be induced voltage in each armature conductor. The direction of the induced voltage can be determined by applying *Fleming's right hand rule*. All the conductors under the influence of North Pole will have directed induced voltage, while the conductors under the influence of South Pole will have induced voltage in them. For a loaded generator the direction of the armature current will be same as that of the induced voltages.

Thus and also represent the direction of the currents in the conductors. We know, a current carrying conductor placed in a magnetic field experiences force, the direction of which can be obtained by applying *Fleming's left hand rule*. Applying this rule to the armature conductors in fig the rotor experiences a torque (T_e) in the counter clockwise direction (i.e., opposite to the direction of rotation) known as back torque. For steady speed operation back torque is equal to the machines input torque (T_{pm}) i.e. the torque supplied by prime mover.

Electromechanical-Energy-Conversion Principles

The electromechanical-energy-conversion process takes place through the medium of the electric or magnetic field of the conversion device of which the structures depend on their respective functions.

- Transducers: microphone, pickup, sensor, loudspeaker
- Force producing devices: solenoid, relay, and electromagnet
- Continuous energy conversion equipment: motor, generator

Forces and Torques in Magnetic Field Systems

$$F_v = J \times B$$

ρ (charge density): coulombs/m^3, F_v (force density): newtons/m^3, $J = \rho v$ (current density): amperes/m^2.

Most electromechanical-energy-conversion devices contain magnetic material.

- Forces act directly on the magnetic material of these devices which are constructed of rigid, non-deforming structures.
- The performance of these devices is typically determined by the net force, or torque, acting on the moving component. It is rarely necessary to calculate the details of the internal force distribution.
- Just as a compass needle tries to align with the earth's magnetic field, the two sets of fields associated with the rotor and the stator of rotating machinery attempt to align, and torque is associated with their displacement from alignment.
  - In a motor, the stator magnetic field rotates ahead of that of the rotor, pulling on it and performing work.
  - For a generator, the rotor does the work on the stator.

The Energy Method

> Based on the principle of conservation of energy: energy is neither created nor destroyed; it is merely changed in form.

> shows a magnetic-field-based electromechanical-energy-conversion device.

- A lossless magnetic-energy-storage system with two terminals
- The electric terminal has two terminal variables: e (voltage), i (current).
- The mechanical terminal has two terminal variables: f_{fld} (force), x (position)
- The loss mechanism is separated from the energy-storage mechanism.

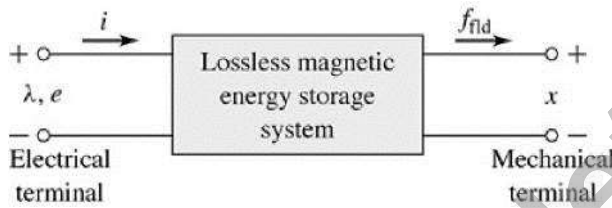
– Electrical losses: ohmic losses...

– Mechanical losses: friction, windage...

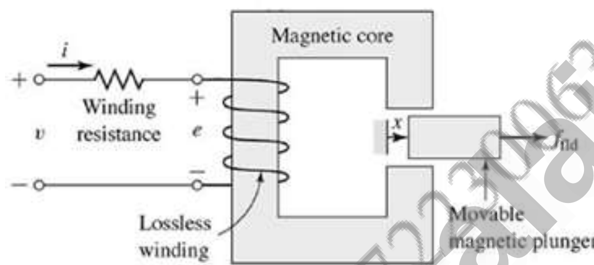
> a simple force-producing device with a single coil forming the electric terminal, and a movable plunger serving as the mechanical terminal.

- The interaction between the electric and mechanical terminals, i.e. the electromechanical energy conversion, occurs through the medium of the magnetic stored energy.

Schematic diagram of magnetic-electromechanical-energy-conversion



field device



Schematic diagram of simple force-producing device

- W_{fld} : the stored energy in the magnetic field

$$\frac{dW_{fld}}{dt} = ei - f_{fld}\frac{dx}{dt}$$

$$e = \frac{d\lambda}{dt}$$

$$dW_{fld} = id\lambda - f_{fld}dx$$

- From the above equation force can be solved as a function of the flux λ and the mechanical terminal position *x*.

- The above equations form the basis for the energy method

Energy Balance

Consider the electromechanical systems whose predominant energy-storage mechanism is in magnetic fields. For motor action, the energy transfer can be accounted as

$$\begin{pmatrix}\text{Energy input}\\ \text{form electric}\\ \text{sources}\end{pmatrix} = \begin{pmatrix}\text{Mechanical}\\ \text{energy}\\ \text{output}\end{pmatrix} + \begin{pmatrix}\text{Increase in energy}\\ \text{stored in magnetic}\\ \text{field}\end{pmatrix} + \begin{pmatrix}\text{Energy}\\ \text{converted}\\ \text{into heat}\end{pmatrix}$$

The ability to identify a lossless-energy-storage system is the essence of the energy method.

> This is done mathematically as part of the modeling process.

> For the lossless magnetic-energy-storage system of Fig. can be rearranged and gives

$$dW_{elec} = dW_{mech} + dW_{fld}$$

where

$dW_{elec} = id\lambda$ = differential electric energy input

$dW_{mech} = f_{fld}dx$ = differential mechanical energy output

dW_{fld} = differential change in magnetic stored energy

>Here e is the voltage induced in the electric terminals by the changing magnetic stored energy. It is through this reaction voltage that the external electric circuit supplies power to the coupling magnetic field and hence to the mechanical output terminals.

$$dW_{elec} = ei\ dt$$

> The basic energy-conversion process is one involving the coupling field and its action and reaction on the electric and mechanical systems.

> Combining above two equation –

$$dW_{elec} = ei\ dt = dW_{mech} + dW_{fld}$$

Energy in Singly-Excited Magnetic Field Systems

In energy-conversion systems the magnetic circuits have air gaps between the stationary and moving members in which considerable energy is stored in the magnetic field.

> This field acts as the energy-conversion medium, and its energy is the reservoir between the

electric and mechanical system.

shows an electromagnetic relay schematically. The predominant energy storage occurs in the air gap, and the properties of the magnetic circuit are determined by the dimensions of the air gap.

$$\lambda = L(x)i$$
$$dW_{\text{mech}} = f_{\text{fld}}dx$$
$$dW_{\text{fld}} = id\lambda - f_{\text{fld}}dx$$

W_{fld} is uniquely specified by the values of λ and x. Therefore, λ and x are referred to as state variables.

Since the magnetic energy storage is lossless, it is conservative system. W_{fld} is the same regardless of how λ and x are brought to their final values.

Integration paths for W_{fld}

On path 2a, $d\lambda$=0 and f_{fld}=0. Thus df_{fld}=0 on path 2a. On path 2b, dx= 0. Therefore the following equation can be written

$$W_{\text{fld}}(\lambda_0, x_0) = \int_0^{\lambda_0} i(\lambda, x_0)d\lambda$$

For a linear system in which λ is proportional to i the equation will change and can be written as-

$$W_{\text{fld}}(\lambda, x) = \int_0^{\lambda} i(\lambda', x)d\lambda' = \int_0^{\lambda} \frac{\lambda'}{L(x)}d\lambda' = \frac{1}{2}\frac{\lambda^2}{L(x)}$$

V: the volume of the magnetic field

$$W_{\text{fld}} = \int_V \left(\int_0^B H.dB' \right) dV$$
$$If\ \ B = \mu H, \text{ then}$$
$$W_{\text{fld}} = \int_V \left(\frac{B^2}{2\mu} \right) dV$$

Determination of Magnetic Force and Torque form Energy

The magnetic stored energy is a state function, determined uniquely by the values of the W_{fld} independent state variables λ and x.

$$dW_{\text{fld}}(\lambda, x) = i\,d\lambda - f_{\text{fld}}\,dx$$

$$dW_{\text{fld}}(\lambda, x) = \left.\frac{\partial W_{\text{fld}}}{\partial \lambda}\right|_x d\lambda + \left.\frac{\partial W_{\text{fld}}}{\partial x}\right|_\lambda dx$$

$$i = \left.\frac{\partial W_{\text{fld}}(\lambda, x)}{\partial \lambda}\right|_x$$

$$\boxed{f_{\text{fld}} = -\left.\frac{\partial W_{\text{fld}}(\lambda, x)}{\partial x}\right|_\lambda}$$

Energy and Co-energy:

It is that energy from which the force can be obtained directly as a function of the current. The selection of energy or co-energy as the state function is purely a matter of convenience.

The co-energy $W'_{\text{fld}}(i, x)$ is defined as a function of I and x such that

$$W'_{\text{fld}}(i, x) = i\lambda - W_{\text{fld}}(\lambda, x)$$

$$d(i\lambda) = i\,d\lambda + \lambda\,di$$

$$dW'_{\text{fld}}(i, x) = d(i\lambda) - dW_{fld}(\lambda, x)$$

$$\boxed{dW'_{\text{fld}}(i, x) = \lambda\,di + f_{\text{fld}}\,dx}$$

From the above equation co-energy $W'_{\text{fld}}(i, x)$ can be seen to be a state function of the two independent variables *i* and *x*.

$$dW'_{\text{fld}}(i, x) = \left.\frac{\partial W'_{fld}}{\partial i}\right|_x di + \left.\frac{\partial W'_{fld}}{\partial x}\right|_i dx$$

$$\lambda = \left.\frac{\partial W'_{\text{fld}}(i, x)}{\partial i}\right|_x$$

$$\boxed{f_{\text{fld}} = \left.\frac{\partial W'_{\text{fld}}(i, x)}{\partial x}\right|_i}$$

For a system with a rotating mechanical displacement,

$$W'_{\text{fld}}(i, \theta) = \int_0^i \lambda(i', \theta)\,di'$$

$$T_{\text{fld}} = \left.\frac{\partial W'_{\text{fld}}(i, \theta)}{\partial \theta}\right|_i$$

If the system is magnetically linear,

$$W'_{\text{fld}}(i,\theta)=\frac{1}{2}L(\theta)i^2$$

$$T_{\text{fld}}=\frac{i^2}{2}\frac{dL(\theta)}{d\theta}$$

In field-theory terms, for soft magnetic materials

$$W'_{\text{fld}}=\int_V\left(\int_0^{H_0}B\cdot dH\right)dV$$

$$W'_{\text{fld}}=\int_v\frac{\mu H^2}{2}dV$$

For permanent-magnet (hard) materials

$$W'_{\text{fld}}=\int_V\left(\int_{H_c}^{H_0}B\cdot dH\right)dV$$

For a magnetically-linear system, the energy and co-energy (densities) are numerically equal:

$$\frac{1}{2}\lambda^2/L=\frac{1}{2}Li^2,\ \frac{1}{2}B^2/\mu=\frac{1}{2}\mu H^2$$

For a nonlinear system in which λ and i or B and H are not linearly proportional, the two functions are not even numerically equal.

$$W_{\text{fld}}+W'_{\text{fld}}=\lambda i$$

Multiply-Excited Magnetic Field Systems

Many electromechanical devices have multiple electrical terminals.

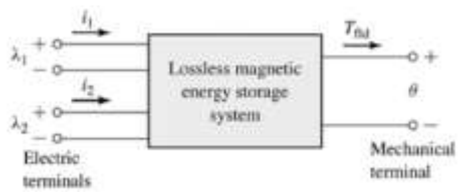
> Measurement systems: torque proportional to two electric signals; power as the product of voltage and current.

> Energy conversion devices: multiply-excited magnetic field system.

> A simple system with two electrical terminals and one mechanical terminal:

Three independent variables: $\{\theta,\lambda_1,\lambda_2\}$, $\{\theta,i_1,i_2\}$, $\{\theta,\lambda_1,i_2\}$, or $\{\theta,i_1,\lambda_2\}$.

$$dW_{\text{fld}}(\lambda_1,\lambda_2,\theta)=i_1d\lambda_1+i_2d\lambda_2-T_{\text{fld}}d\theta$$



Multiply-excited magnetic energy storage system

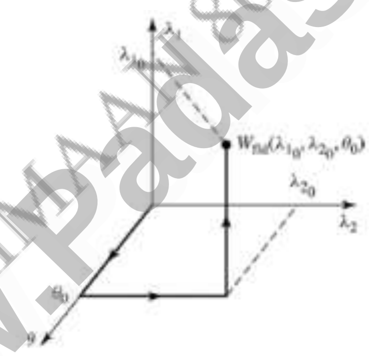
$$i_1 = \left.\frac{\partial W_{\text{fld}}(\lambda_1,\lambda_2,\theta)}{\partial \lambda_1}\right|_{\lambda_2,\theta}$$

$$i_2 = \left.\frac{\partial W_{\text{fld}}(\lambda_1,\lambda_2,\theta)}{\partial \lambda_2}\right|_{\lambda_1,\theta}$$

$$\boxed{T_{\text{fld}} = -\left.\frac{\partial W_{\text{fld}}(\lambda_1,\lambda_2,\theta)}{\partial \theta}\right|_{\lambda_1,\lambda_2}}$$

To find $W_{\text{fld},}$ use the path of integration as shown i

$$W_{\text{fld}}(\lambda_{1_0},\lambda_{2_0},\theta_0) = \int_0^{\lambda_{2_0}} i_2(\lambda_1 = 0,\lambda_2,\theta=\theta_0)\,d\lambda_2 + \int_0^{\lambda_{1_0}} i_1(\lambda_1,\lambda_2=\lambda_{2_0},\theta=\theta_0)\,d\lambda_1$$



Integration path to obtain $W_{\text{fld}}(\lambda_{10}, \lambda_{20}, \theta_0)$

> In a magnetically-linear system,

$$\lambda_1 = L_{11} i_1 + L_{12} i_2$$

$$\lambda_2 = L_{21} i_1 + L_{22} i_2$$

$$L_{12} = L_{21}$$

Note that $L_{ij} = L_{ij}(\theta)$

$$i_1 = \frac{L_{22}\lambda_1 - L_{12}\lambda_2}{D}$$

$$i_2 = \frac{-L_{21}\lambda_1 + L_{11}\lambda_2}{D}$$

$$D = L_{11}L_{22} - L_{12}L_{21}$$

The energy for this linear system is

$$W_{\text{fld}}(\lambda_{1_0},\lambda_{2_0},\theta_0)=\int_0^{\lambda_{2_0}}\frac{L_{11}(\theta_0)\lambda_2}{D(\theta_0)}d\lambda_2+\int_0^{\lambda_{1_0}}\frac{\left(L_{22}(\theta_0)\lambda_1-L_{12}(\theta_0)\lambda_{2_0}\right)}{D(\theta_0)}d\lambda_1$$

$$=\frac{1}{2D(\theta_0)}L_{11}(\theta_0)\lambda_{2_0}^2+\frac{1}{2D(\theta_0)}L_{22}(\theta_0)\lambda_{1_0}^2-\frac{L_{12}(\theta_0)}{D(\theta_0)}\lambda_{1_0}\lambda_{2_0}$$

Co-energy function for a system with two windings can be defined as

$$W'_{\text{fld}}(i_1,i_2,\theta)=\lambda_1 i_1+\lambda_2 i_2-W_{\text{fld}}$$

$$dW'_{\text{fld}}(i_1,i_2,\theta)=\lambda_1 di_1+\lambda_2 di_2+T_{\text{fld}}d$$

$$\lambda_1=\left.\frac{\partial W_{\text{fld}}(i_1,i_2,\theta)}{\partial i_1}\right|_{i_2,\theta}$$

$$\lambda_2=\left.\frac{\partial W_{\text{fld}}(i_1,i_2,\theta)}{\partial i_2}\right|_{i_1,\theta}$$

$$\boxed{T_{\text{fld}}=\left.\frac{\partial W'_{\text{fld}}(i_1,i_2,\theta)}{\partial\theta}\right|_{i_1,i_2}}$$

$$W'_{\text{fld}}(i_1,i_2,\theta_0)=\int_0^{i_{2_0}}\lambda_2(i_1=0,i_2,\theta=\theta_0)di_2+\int_0^{i_{1_0}}\lambda_1(i_1,i_2=i_{2_0},\theta=\theta_0)di_1$$

For a linear system

$$W'_{\text{fld}}(i_1,i_2,\theta_0)=\frac{1}{2}L_{11}(\theta)i_1^2+\frac{1}{2}L_{22}(\theta)i_2^2+L_{12}(\theta)i_1 i_2$$

$$T_{\text{fld}}=\left.\frac{\partial W'_{\text{fld}}(i_1,i_2,\theta_0)}{\partial\theta}\right|_{i_1,i_2}=\frac{i_1^2}{2}\frac{dL_{11}(\theta)}{d\theta}+\frac{i_2^2}{2}\frac{dL_{22}(\theta)}{d\theta}+i_1 i_2\frac{dL_{12}(\theta)}{d\theta}$$

- Note that the co-energy function is a relatively simple function of displacement.
- The use of a co-energy function of the terminal currents simplifies the determination of torque or force.

Action of Commutator

In DC machines the current in each wire of the armature is actually alternating, and hence a device is required to convert the alternating current generated in the DC generator by electromagnetic induction into direct current, or at the armature of a DC motor to convert the input direct current into alternating

DC generator: induced AC *emf* is converted to DC voltage; DC motor: input direct current is converted to alternating current in the armature at appropriate times to produce a unidirectional torque. The commutator consists of insulated copper segments mounted on an insulated tube. Armature coils are connected in series through the commutator segments.

Two brushes are pressed to the commutator to permit current flow. The brushes are placed in the neutral zone, where the magnetic field is close to zero, to reduce arcing. The *commutator* switches the current from one rotor coil to the adjacent coil. The switching requires the interruption of the coil current. The sudden interruption of an inductive current generates high voltages. The high voltage produces flashover and arcing between the commutator segment and the brush.

Constructional Features

* The stator of the dc machine has poles, which are excited by dc current to produce magnetic fields.
* In the neutral zone, in the middle between the poles, commutating poles or interpoles are placed to reduce sparking of the commutator due to armature reaction.
* The commutating poles are supplied by dc current. Compensating windings are mounted on the main poles. Field poles are mounted on an iron core that provides a closed magnetic circuit.
* The motor housing supports the iron core, the brushes and the bearings.
* The rotor has a ring-shaped laminated iron core with slots. Coils with several turns are placed in the slots.
* The distance between the two legs of the coil is about 180 electric degrees for full pitch.
* The coils are connected in series through the commutator segments.
* The ends of each coil are connected to a commutator segment.

Armature of DC Machine

Armature Winding

DC machines armature consists of armature conductors. The conductors distributed in slots provided on the periphery of the armature is called armature winding. Depending on the way in which the coils are interconnected at the commutator end of the armature, the windings can be classified as lap and wave windings. Further they can be classified as simplex and multiplex.

Coil Span/Coil Pitch:

It represents the span of the coil. For full pitched winding, the span is 180^0 electrical or number of slots per pole. Coil pitch can be represented in terms of electrical degrees, slots or conductor. A full pitched coil leads to maximum voltage per coil.

Back Pitch *(Yb)*:

It is the distance measured in between the two coil sides of the same coil at the back end of the armature, the commutator end being the front end of armature. It can be represented in terms of number of slots or coil sides. Back pitch also represents the span of coil.

Front Pitch (*Yf*):

The distance between the two coil sides of two different coils connected in series at the front end of the armature is called front pitch.

Lap Winding

Lap winding is suitable for low voltage high current machines because of more number of parallel paths. The number of parallel path in lap winding is equal to number of poles.

$$A=P$$

Equalizing rings are connected in lap winding.

Wave Winding

Wave winding is used for high voltage low current machines. In case of wave winding, the number of parallel path (A) = 2 irrespective of number of poles. Each path will have conductors connected in series.

Equalizing rings are not required in wave winding.

Simplex and Multiplex Winding

The degree of multiplicity of a multiplex winding indicates the relative number of parallel paths with respect to the number of parallel paths in the corresponding simplex winding. For example a duplex lap or wave winding is a lap or wave winding having twice as many as parallel paths as a simplex lap or wave winding respectively. The winding can be triplex or quadruplex winding in similar manner.

Use of Laminated Armature

The armature winding of DC machine should be laminated to reduce eddy current losses. The armature body (rotor) rotates in the field magnetic field. Thus in the core of the armature voltage induced which in turn causes current to flow in the body. This current is known as eddy current. This current causes loss and thus heat will be generated. This loss depends on the amount of current flow. To reduce the amount of current flow the resistance of the body should be increased. Thus using lamination the resistance of the path through which current flows will be increased. The amount of eddy current will be reduced and thus eddy current loss can be minimized.

EMF Equation

Let Flux cut by a conductor in one revolution $= d\phi = P\phi$ weber.

Since Number of revolutions/second$= \frac{N}{60}$

Time taken for one revolution $= dt = \frac{60}{N}$ seconds

EMF generated/conductor $= \frac{d\phi}{dt} = \frac{P\phi}{\frac{60}{N}} = \frac{P\phi N}{60}$

Since each path has $\frac{Z}{A}$ conductors in series,

EMF generated in each path is $E = \frac{P\phi N}{60} \times \frac{Z}{A}$

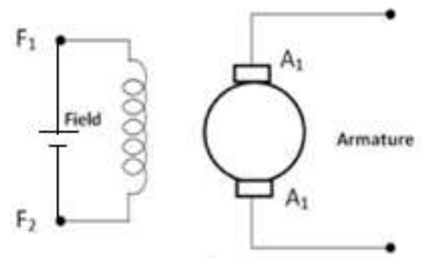
$$\boxed{E = \frac{P\phi ZN}{60A}}$$

Methods of excitation

DC machines are excited in two ways-

Separate excitation:

When the field winding is connected to an external source to produce field flux. According to the type of excitation this machines are called separately excited dc machine.



Schematic diagram of separately excited dc machine

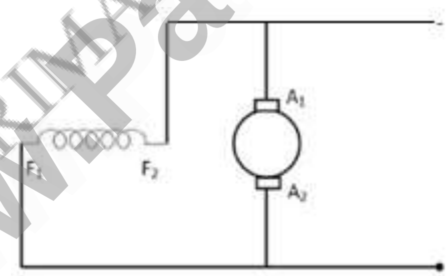
Self-excitation:

When the field winding is connected with the armature to produce field flux. A self-excited machine requires residual magnetism for operation. According to the type of excitation this machines are called self-excited dc machine.

Depending on the type of field winding connection DC machines can be classified as:

Shunt machine:

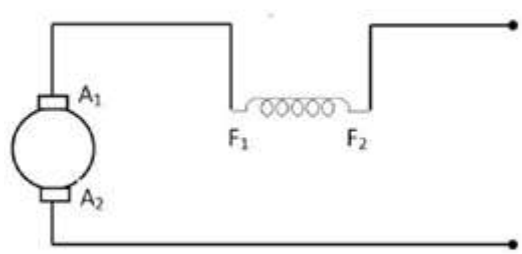
The field winding consisting of large number of turns of thin wire is usually excited in parallel with armature circuit and hence the name shunt field winding. This winding will be having more resistance and hence carries less current.



Schematic diagram of dc shunt machine

Series machine:

The field winding has a few turns of thick wire and is connected in series with armature.



Schematic diagram of dc series machine

Compound machine:

Compound wound machine comprises of both series and shunt windings and can be either short shunt or long shunt, cumulative, differential or flat compounded.

Build-up of E.M.F

When the armature is rotating with armature open circuited, an emf is induced in the armature because of the residual flux. When the field winding is connected with the armature, a current flows through the field winding (in case of shunt field winding, field current flows even on No-load and in case of series field winding only with load) and produces additional flux. This additional flux along with the residual flux generates higher voltage. This higher voltage circulates more current to generate further higher voltage. This is a cumulative process till the saturation is attained.

Process of voltage build-up in DC generator

Here OM is the field resistance curve. Initially there will be residual voltage which will create OA field current. This field current will increase the existing magnetic field and the induced voltage will increase up-to OB.

This OB voltage will further applied to the field winding and increase the field current to OC. This process will continue upto the point L where the emf curve intersect with field resistance and finally the induced voltage will be OJ. This way voltage builds-up in dc generator.

Critical Resistance:-

The voltage to which it builds is decided by the resistance of the field winding as shown in the figure If field circuit resistance is increased such that the resistance line does not cut OCC like ‘OP’ in the then the machine will fail to build up voltage to the rated value.

The slope of the air gap line drawn as a tangent (OQ) to the initial linear portion of the curve represents the maximum resistance that the field circuit can have beyond which the machine fails to build up voltage.

This value of field circuit resistance is called critical field resistance. The field circuit is generally designed to have a resistance value less than this so that the machine builds up the voltage to the rated value.

Field current vs No-load voltage for different field resistances

Critical field resistance is defined as the maximum field circuit resistance for a given speed with which the shunt generator would excite. The shunt generator will build up voltage only if field circuit resistance is less than critical field resistance.

Critical Speed:

Voltage of a dc generator is proportional to its speed. Thus when speed will be reduced then the induced voltage will reduced. There can be such situation occur when the speed will be so low that the existing field winding resistance voltage bulid up will not occur. The speed of the generator can be lowered upto a certain level. This minimum value of the speed of the generator for which the generator can excite is called critical speed. It can also define as that speed of a generator for which the existing field resistance of generator becomes its critical field resistance.

Field current vs No-load voltage for different speed

In the above figure it is showing that when speed of the generator changes from n1 to n2 and then n3 emf production changes accordingly. Here n1>n2>n3. For speed n3 voltage build-up is not possible. The speed n2 is the critical speed. As shown in the figure at speed n2 generator field resistance become its critical field resistance.

Causes for failure to self-excite and its remedial

i. The field poles may not have residual magnetism. Then the generator will fail to excite.

   Then to restore residual magnetism field winding should be connected to an external dc voltage source. This is called flashing of field.

ii. When the direction of rotation is not proper such that flux produced by the field current reinforces the residual magnetism.

   The rotation of the machine has to be reversed.

iii. The field winding resistance is more than critical resistance then the machine will fail to excite.

   The field winding resistance should be less than critical field resistance.

iv. When the speed of the machine is less than critical speed.

   The machine's speed should be more than critical speed.

v. If the field winding connections are such that newly generated field flux is working in opposite to the existing residual magnetism. Then the generator will fail to excite.

Then the field winding connection should be reversed.

Armature Reaction

The action of magnetic field set up by armature current on the distribution of flux under main poles of a DC machine is called armature reaction.

When the armature of a DC machines carries current, the distributed armature winding produces its own mmf. The machine air gap is now acted upon by the resultant mmf distribution caused by the interaction of field ampere turns (AT_f) and armature ampere turns (AT_a). As a result the air gap flux density gets distorted.

The axis of the main poles is called the direct axis (d-axis) and the interpolar axis is called quadrature axis (q-axis). It can be seen from the Figure b that armature mmf (F_a) is along the interpolar axis. F_a which is at 90^0 to the main field axis is known as cross magnetizing mmf.

shows the practical condition in which a DC machine operates when both the Field flux and armature flux are existing. Because of both fluxes are acting simultaneously, there is a shift in brush axis and crowding of flux lines at the trailing pole tip and flux lines are weakened or thinned at the leading pole tip. (The pole tip which is first met in the direction of rotation by the armature conductor is leading pole tip and the other is trailing pole tip).

If the iron in the magnetic circuit is assumed unsaturated, the net flux/pole remains unaffected by the armature reaction though the air gap flux density distribution gets distorted. If the main pole excitation is such that the iron is in the saturated region of magnetization (practical case) the increase in flux density at one end of the poles caused by armature reaction is less than the decrease at the other end, so that there is a net reduction in the flux/pole. This is called the demagnetizing effect. Thus it can be summarized that the nature of armature reaction in a DC machine is

1. Cross magnetizing with its axis along the q-axis.
2. It causes no change in flux/pole if the iron is unsaturated but causes reduction in flux/pole in the

presence of iron saturation. This is termed as demagnetizing effect.

Cross Magnetizing Ampere Turns/pole(AT_c)

f the brush is shifted by an angle θ as shown then the conductors lying in between the angles BOC and DOA are carrying the current in such a way that the direction of the flux is downwards
i.e., at right angles to the main flux. This results is the distortion in the main flux. Hence, these conductors are called cross magnetizing or distorting ampere conductors.

Total armature conductors/pole= $\frac{Z}{P}$

Demagnetizing conductors / pole = $Z\frac{2\theta}{360}$

Therefore cross magnetizing conductors/pole= $\frac{Z}{P} - Z\frac{2\theta}{360}$

Cross magnetizing ampere turns/pole AT_c= $\frac{ZI_a}{a}\left(\frac{1}{2P} - \frac{\theta}{360}\right)$

Demagnetizing Ampere Turns /pole (AT_d)

The exact conductors which produce demagnetizing effect are shown, Where the brush axis is given a forward lead of θ so as to lie along the new axis of M.N.A. The flux produced by the current carrying conductors lying in between the angles AOC and BOD is such that, it opposes the main flux and hence they are called as demagnetizing armature conductors.

Current in each armature conductors= $\frac{I_a}{a}$

θ =Forward lead in mechanical or angular deg.

Total no of armature conductors in between angles AOC & BOD = $\frac{4\theta}{360}Z$

Demagnetizing amp turns/poles AT_d = $\frac{Z\theta I_a}{360a}$

Compensating Winding

Due to armature reaction flux density wave get distorted and reduced. Due to distortion of flux wave the peak flux density increases to such a high value that it creates high induced emf. If this emf is higher than the breakdown voltage across adjacent segments, a spark over could result which can easily spread over the whole commutator, and there will be a ring of fire, resulting in the complete short circuit of the armature.

To protect armature from such adverse condition armature reaction must be neutralized. To neutralize the armature reaction ampere-turns by compensating winding placed in the slots cut out in pole face such that the axis of the winding coincides with the brush axis.

The compensating windings neutralize the armature mmf directly under the pole which is the major portion because in the interpole region the air gap will be large. Compensating windings are connected in series with armature so that it will create mmf proportional to armature mmf.

The number of ampere-turns required in the compensating windings is given by

$$AT_c = \text{Total Armature Ampere Turns} \times \frac{\text{Pole Arc}}{\text{Pole Pitch}}$$

Commutation

The process of reversal of current in the short circuited armature coil is called 'Commutation'. This process of reversal takes place when coil is passing through the interpolar axis (q-axis), the coil is short circuited through commutator segments and brush.

The current is changed from +20 to –20. So due to self inductance and variation in the current from +20 to –20, a voltage is induced in the coil which is given by L dI/dt. This emf opposes the change in current in coil 'CD' thus sparking occurs.

Reactance Voltage

During commutation sparking occurs in the commutator segment and brush due to presence of reactance voltage. This voltage is generated due to change of current in the commutating coil for its self-inductance and also due to mutual inductance of the adjacent coils. This voltage is called reactance voltage and according to Lenz's law this induced voltage oppose its cause of production.

Reactance voltage = co-efficient of self-inductance X rate of change of current= $L\frac{di}{dt}$

$$=1.11L\frac{2I}{T_c} \text{ for sinusoidal commutation}$$

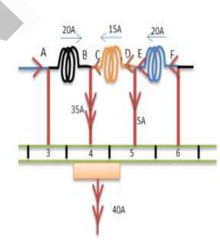
Total change in current = I - (-I) = 2I

Therefore self-induced or reactance voltage = $L\frac{2I}{T_c}$ for linear commutation

If brush width is given in terms of commutator segments, then commutator velocity should be converted in terms of commutator segments/seconds.

Method of Improving Commutation

Commutation can be improved in two ways by (i) Resistance commutation
(ii) E.M.F commutation.



Resistance Commutation

The first path is straight from bar '5' to the brush and the other is via short circuited coil 'CD' to bar '4' and then to brush. If copper brushes are used the current will follow the first path because of its low contact resistance. But when carbon brushes having high resistance are used, then current '20A' will prefer the second path because the resistance r_1 of first path will increase due to reducing area of contact with bar '5' and the resistance r_2 of second path decreases due to increasing area of contact with bar '4'. Hence carbon brushes help in obtaining sparkles commutation. Also, carbon brushes lubricate and polish commutator. But, because of high resistance the brush contact drop increases and the commutator has to be made larger to dissipate the heat due to loss. Carbon brushes require larger brush holders because of lower current density.

E.M.F commutation:

To neutralize sparking caused by reactance voltage in this method an emf is producied whichacts in opposite direction to that of reactance voltage, so that the reactance voltage is completely eliminated. The neutralization of emf may be done in two ways (i) by giving brush a forward lead sufficient enough to bring the short circuited coil under the influence of next pole of opposite polarity.

TO BE CONTINUED.....

TRB-POLYTECHNIC LECTURER-(NEW SYLLABUS) STUDY MATERIALS AVAILABLE

- MATHEMATICS STUDY MATERIAL with Question Bank.
- ENGLISH STUDY MATERIAL with Question Bank.
- PHYSICS STUDY MATERIAL with Question Bank.
- CHEMISTRY STUDY MATERIAL with Question Bank.
- MODERN OFFICE PRACTICE STUDY MATERIAL with Q.B.
- COMPUTER SCIENCE STUDY MATERIAL with Question Bank.
- INFORMATION TECHNOLOGY STUDY MATERIAL with Q.Bank.
- ECE STUDY MATERIAL with Question Bank.
- EEE STUDY MATERIAL With Question Bank.
- MECHANICAL STUDY MATERIAL With Question Bank.
- CIVIL STUDY MATERIAL With Question Bank.
- EIE STUDY MATERIAL with Question Bank.
- ICE STUDY MATERIAL with Question Bank.

UG-TRB MATERIALS

- UG TRB: TAMIL MATERIAL WITH QUESTION BANK.
- UG TRB: ENGLISH STUDY MATERIAL +Q. BANK (T/M)

- UG-TRB: MATHEMATICS MATERIAL WITH Q. BANK (E/M)
- UG TRB: PHYSICS MATERIAL WITH QUESTION BANK (E/M)
- UG TRB: CHEMISTRY MATERIAL + QUESTION BANK (E/M)
- UG TRB: HISTORY MATERIAL + Q.BANK (T/M & E/M)
- UG TRB: ZOOLOGY MATERIAL + QUESTION BANK (E/M)
- UG TRB: BOTANY MATERIAL +QUESTION BANK (T/M& E/M)
- UG TRB: GEOGRAPHY STUDY MATERIAL (E/M)

SCERT/DIET/GTTI (LECTURER) STUDY MATERIAL AVAILABLE.

PG-TRB MATERIALS

- PG TRB: ENGLISH MATERIAL WITH QUESTION BANK.
- PG TRB: TAMIL STUDY MATERIAL +QUESTION BANK (T/M)
- PG-TRB: MATHEMATICS MATERIAL WITH Q.BANK (E/M)
- PG TRB: PHYSICS MATERIAL WITH QUESTION BANK (E/M)
- PG TRB: CHEMISTRY MATERIAL + QUESTION BANK (E/M)
- PG TRB: COMMERCE MATERIAL WITH Q.BANK (T/M)&(E/M)
- PG TRB:ECONOMICS MATERIAL+Q. BANK (T/M & E/M)