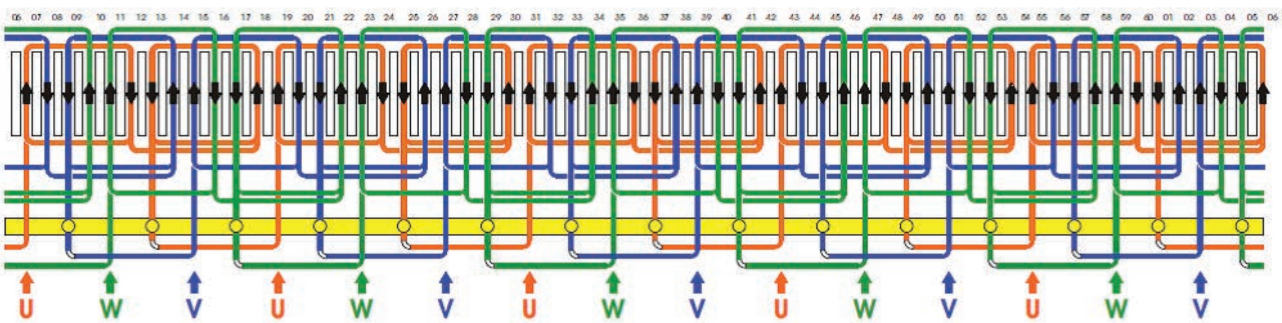
Chapter 9

DC and AC Windings

4GTTPJ



You cannot believe in God until you believe in yourself.
- **Swamy Vivekanadar**

Learning Objectives

Winding is the heart of motors and generators. It is important to keep the windings in good condition for the satisfactory operations of the electrical machines used in our houses and industries. If we have basic knowledge and experience in knowing all details about motor's rewinding procedure, not only it helps to know the operation of motors and generators but also to the self-employment. There are number of persons in the motor rewinding field by their own experience, without any proper studies in the electrical engineering field. If our students get good experience with proper knowledge details about motor rewinding, there is no doubt in becoming great achievers this field.

Table of Content

9.1 Introduction

Windings are used in the electrical field such as motors, generators, transformers, loud speakers and in all kinds of electrical measuring instruments. The main objective of the use of winding is to produce the magnetic field according to the capacity of the electrical machines. In this lesson, we have to learn about the materials needed for making the windings and different types of DC and AC windings.

9.2 Winding materials

Generally two types of important materials are used in the process of winding the motors and generators. They are,

i. Electric conductors
ii. Electrical insulating materials.

i. Electric conductors

Materials having low resistance allows the electric current to flow easily through conductors are called as electric conductors. Generally, it is made up of metals. For winding, copper conductors are mainly used for making coils and aluminium conductors are used next.

a. Types of conductors

For the following windings are the types of conductors commonly used.

i. Cotton covered winding wires.
ii. Silk covered winding wires.
iii. Paper covered winding wires.
iv. Varnished glass paper covered winding wires.
v. Enamel coated round shaped winding wires.

Enamel coated round wires are mainly used in small and medium type of motors having semi-closed slots while rectangular conductors are used in larger types of motors having open type slots.

ii. Electrical insulating materials

Materials having very high resistance and also having property not to permit the electric current through them are called insulating materials.

a. Varnishes

It helps the winding to improve the insulation resistance, dielectric strength and mechanical strength. It is used to protect the windings from dust and moisture. It is also used to give coating on the moisture absorbing materials.

9.3 Wire gauge plate

9.3.1 Methods of representing the size of the winding wires

The sizes of the conductors may be notified in two ways as follows,

i. By SWG numbers – a steel "Wire Gauge Plate" is used
ii. By its diameter in millimeter by metric method – An instrument micrometer (Screw gauge) is used.

To Find gauge number of a conductor by using standard wire gauge plate

The sizes and the gauge of the wires can be found by a device called standard gauge plate, which consists of a circular steel plate having notches of different widths around their edges. The diameter of the plate will be generally in 3 ¾ inches (95mm) with thirty six notches. Each notch is stamped with a number. The size

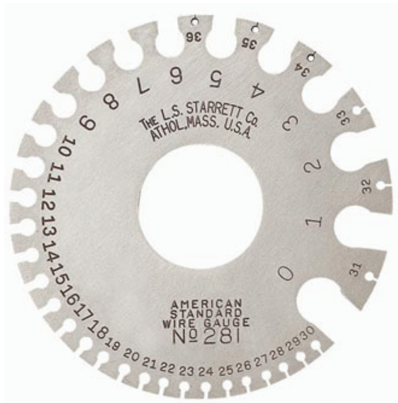


Fig. 9.1 **Standard wire gauge plate**

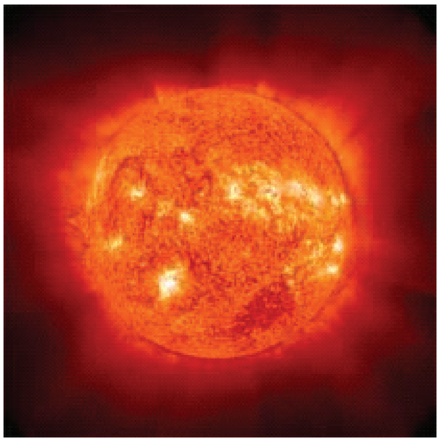
of the conductor to be found is inserted into the notches. The wire which just fits with a particular notch, stated to be the exact size of the wire. The number represented near that notch will be the gauge number of that wire.

By finding gauge number of a wire, we can determine the amount of electric current the wire can safely carry, as well as its electrical resistance and weight per unit length.

We can measure the diameter of the winding wire by using the instrument micrometer (screw gauge). After measuring the diameter of the wire, using the above instrument, we can find the gauge number of the wire from the following table given below.

S.W.G	Standard wire gauge SWG			SWG	Standard wire gauge SWG		
No	Inch	mm	Area mm^2	No	Inch	mm	Area mm^2
0	0.324	8.23	53.17	26	0.018	0.457	0.164
1	0.3	7.62	45.6	27	0.016	0.417	0.136
2	0.276	7.01	38.6	28	0.015	0.376	0.111
3	0.252	6.401	32.2	29	0.014	0.345	0.0937
4	0.232	5.893	27.3	30	0.012	0.315	0.0779
5	0.212	5.385	22.8	31	0.012	0.295	0.0682
6	0.192	4.877	18.7	32	0.011	0.274	0.0591
7	0.176	4.47	15.7	33	0.01	0.254	0.0507
8	0.16	4.064	13	34	0.009	0.234	0.0429
9	0.144	3.658	10.6	35	0.008	0.213	0.0357
10	0.128	3.251	8.3	36	0.008	0.193	0.0293
11	0.116	2.946	6.82	37	0.007	0.173	0.0234
12	0.104	2.642	5.48	38	0.006	0.152	0.0182
13	0.092	2.337	4.29	39	0.005	0.132	0.0137
14	0.08	2.032	3.24	40	0.005	0.122	0.0117
15	0.072	1.829	2.63	41	0.004	0.112	0.0098
16	0.0064	1.626	2.07	42	0.004	0.102	0.0082
17	0.056	1.422	1.59	43	0.004	0.091	0.0065
18	0.048	1.219	1.17	44	0.003	0.081	0.0636
19	0.04	1.016	0.811	45	0.003	0.071	0.0557
20	0.036	0.914	0.657	46	0.002	0.061	0.0479
21	0.032	0.813	0.519	47	0.002	0.051	0.04
22	0.028	0.711	0.397	48	0.002	0.041	0.0322
23	0.024	0.61	0.292	49	0.001	0.03	0.0236
24	0.022	0.559	0.245	50	0.001	0.025	0.0196
25	0.02	0.508	0.203	BASIS: IS 13730-0-1/IEC 317-0-1			

Do you Know?



The electrical energy to earth for one year can be produced by the sun in 15 minutes.

9.4 Details about coils

9.4.1 Coils

A coil consists of a single turn or it may consists of many turns connected in series. Each coil having two coil sides as shown in the figure 9.2.

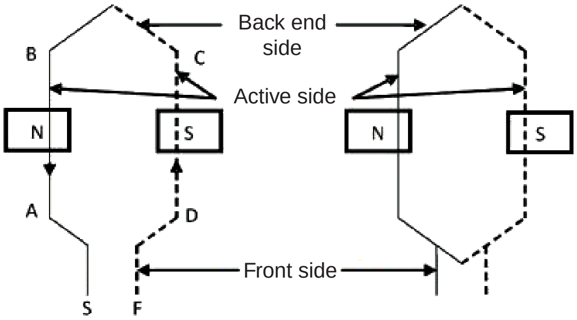


Fig. 9.2 **Winding coil representation**

9.4.2 Active side of a coil

A part of the coil placed in the slots is called as active side. Magnetic field or EMF is induced in this part and hence it is called as active side of the coil.

9.4.3 Inactive side of a coil

The part of the coil which comes out from the slots of a motor is called as inactive side. Here no magnetic field and emf is induced and hence it is called as inactive side of the coil. It is also called as "overhang" part of the coil.

9.4.4 Winding

Winding is made up of many coils with proper connections between them.

9.4.5 Winding diagram

The diagram which describes the type of winding, coil group, coil group connection, phase connection etc. for doing winding is called winding diagram.

9.4.6 Types of winding

Winding types are mainly classified into two types. They are,

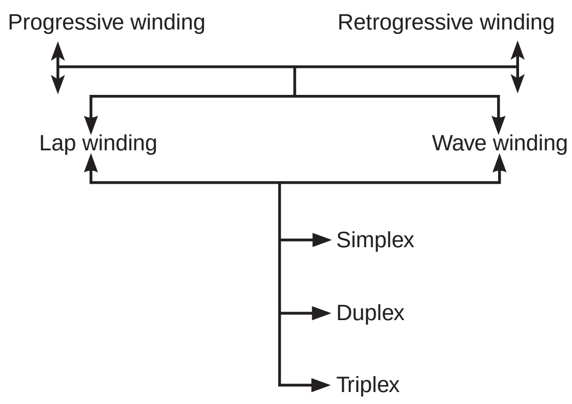
i. DC winding (for DC machines)
ii. AC winding (for AC machines)

9.5 DC windings

Windings are placed in two parts of the DC machines, they are

i. Field winding placed in main poles.
ii. Armature winding placed in armature.

Types of winding in armatures



9.5.1 Progressive winding

In progressive winding, finishing end of a coil is connected to the starting end of a coil which is placed in the right side of the starting point as shown in the figure 9.3.

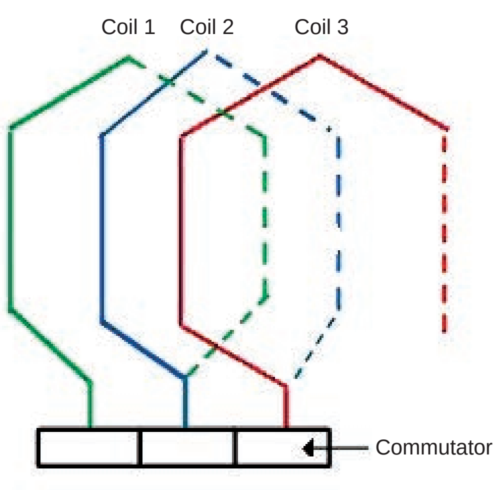


Fig. 9.3 **Progressive lap winding**

9.5.2 Retrogressive winding

In Retrogressive winding, finishing end of a coil is connected to the starting end of a coil which is placed in the left side of the starting point as shown in the figure 9.4.

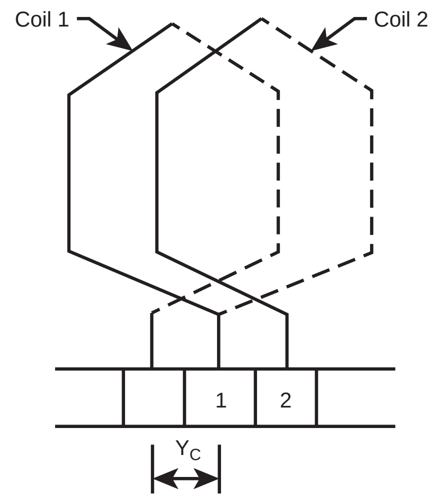


Fig. 9.4 **Retrogressive winding**

9.5.3 Lap winding

As shown in the figure 9.5, winding in which successive coils arranged in the manner that they overlap each other is called Lap winding.

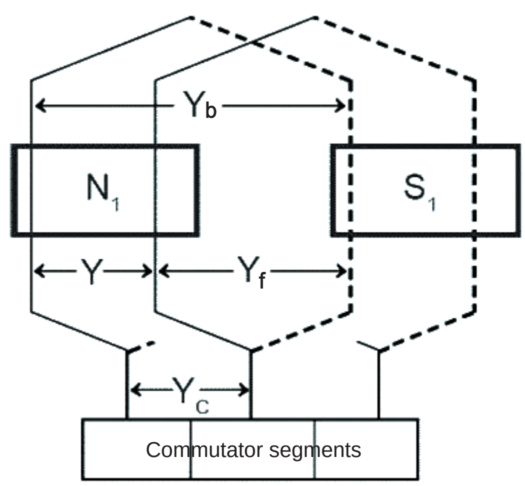


Fig. 9.5 **Lap winding**

9.5.4 Wave winding

As shown in the figure 9.6, winding in which successive coils arranged in the manner that it does not overlap each other and it forms like a wave form and hence it is called wave winding.

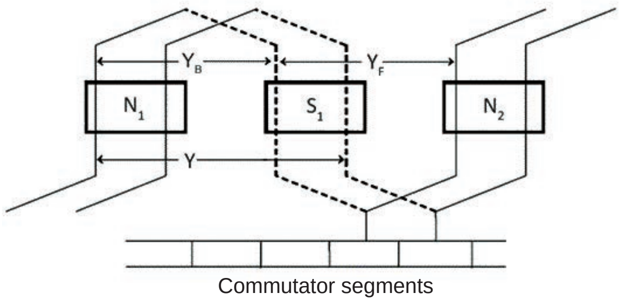


Fig. 9.6 **Wave winding**

9.5.5 Simplex lap winding

In simplex lap winding, finishing end of the first coil is connected with the starting end of the adjacent coil as shown in the figure 9.7.

Here, only one circuit is available.

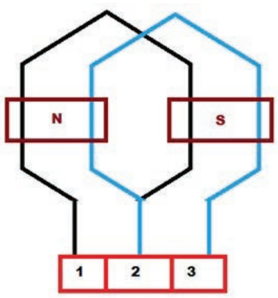


Fig. 9.7 **Simplex lap winding**

9.5.6 Duplex lap winding

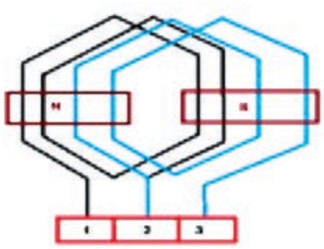


Fig. 9.8 **Duplex lap winding**

In duplex lap winding, finishing end of the first coil is connected with the starting end of the third coil as shown in the figure 9.8. There are two separated circuits in duplex windings.

Coils for the 1st circuit - 1,3,5,7, …..
Coils for the 2nd circuits - 2,4,6,8, ...

9.5.7 Back pitch (Y_b)

The distance between two coil sides of a coil is referred to as back pitch. It is always an odd number.

9.5.8 Winding pitch (or) coil pitch (y)

The distance between two starting leads of successive coils is referred to as winding pitch or coil pitch. It should be always an even number.

9.5.9 Front pitch (y_f)

It is the distance between two coil sides connected to the same commutator segment. It should be an odd number.

9.5.10 Necessary details needed for DC winding

i. First calculate the number of coils. The number of coils must be equal to the number of commutator segments.

ii. According to the formula concerned to the lap or wave winding, calculate the Back pitch (Y_b) Coil pitch (Y), and the Front pitch (Y_f)

iii. Back pitch and front pitch must be of odd number only and the coil pitch must be of even number.

iv. Formula for lap winding

$$\text{Back pitch, } Y_b = \frac{2C}{P} \pm K$$

Here, C – number of coils
P – number of poles

K–whole number a decimal or a fraction needed for making back pitch as an odd number.

Coil pitch, Y = ± 2m
m = 1 for simplex winding
m = 2 for duplex winding

Here '+' symbols denotes the progressive winding while '-' sign denotes the retrogressive winding. Generally all machines are winded by progressive method and hence we are using this type of winding methods in this lesson.

Front pitch, $Y_f = Y_b - Y$

v. Formula for wave winding

$$\text{Back pitch, } Y_b = \frac{2C}{P} \pm K$$

Here also 'C' denotes the number of coils and 'P' denotes the number of poles and the 'K' may be a whole number or a decimal or a fraction needed for making back pitch as an odd number.

$$\text{Coil pitch, } Y = \frac{2C \pm 2m}{P/2}$$

Here, m = 1 (for simplex)

m = 2 (for duplex)

Front pitch, $Y_f = Y\text{-}Y_b$

In wave winding, back pitch and front pitch must be equal.

Hence, $Y_b = Y_f$

vi. In double layer windings, the top layer coils should be numbered by odd numbers and the bottom layer should be numbered by even numbers.

vii. To find the current directions, use Fleming's right hand rule for generators and use Fleming's left hand rule for motors.

viii. The number of brushes must be equal to the number of parallel paths. For lap winding, the number of parallel paths will be equal to the number of poles and for wave winding, the number of parallel paths should be equal to 2

Hence, for lap winding,

Number of brushes = number of poles

For wave winding,
Number of brushes = 2

ix. Mark positive brush connected lead as 'A' and negative brush connected lead as "AA"
These two leads will be the armature leads of the D.C machine.

x. Draw solid vertical lines of equal length for the top layer coil sides and draw dotted vertical lines of same length for the bottom layer coil sides.

9.5.11 Double layer simplex Lap winding diagram

Draw the double layer simplex lap winding diagram for a 2 poles, 6 slots DC machine having 6 commutator segments. Indicate the position of brushes.

Solution

Number of poles P = 2
Number of slots S = 6
Number of commutator segments = 6

We know,

No. of coils C = No.of commutator segments

Hence, C = 6

Back pitch, $Y_b = \frac{2C}{P} \pm K$

$= \frac{2X6}{2} \pm K$

= 6 + 1 = 7 (or)

6-1 = 5

Coil pitch, Y = ±2m

m = 1 (for simplex)

Then, Y= 2 X 1 =2

Front pitch, $Y_f = Y_b - Y$

= 7 – 2 = 5 (or)

5 - 2 = 3

Selected Y_b and Y_f are

$Y_b = 7$

$Y_f = 5$

Winding table

Sl. No.	$Y_b = 7$	$Y_f = 5$
1	1	8
2	3	10
3	5	12
4	7	14(2)
5	9	16(4)
6	11	18(6)

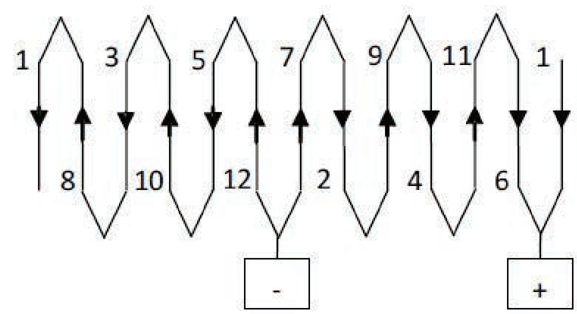


Fig. 9.9 Winding-commutator connection

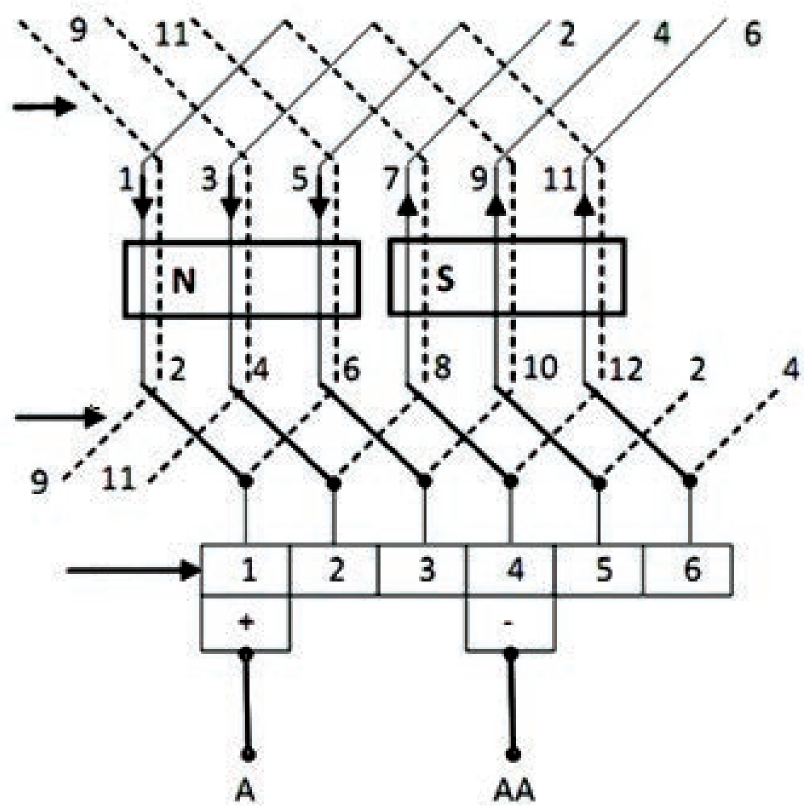


Fig. 9.10 2 Poles 6 slot simplex lap winding diagram

The winding of DC machines shorts from the first coil side and finally ended with the same and hence the DC machines windings are generally called as "closed coil winding".

In making winding table for lap winding, it is important that we must add back pitch to obtain back end side and subtract front pitch to obtain front end side.

9.5.12 Double layer simplex wave winding diagram

Develop a double layer simplex wave winding diagram for a 2 poles, 6 slots, DC machine having 6 commutator segments. Indicate the position of brushes.

Solution

Number of poles P = 2

Number of slots S = 6

Number of commutator segments = 6

We know

No. of coils C = No. of commutator segments

Hence C = 6

$$\text{Back pitch } Y_b = \frac{2C}{P} \pm K$$

$$= \frac{2\times 6}{2} \times K$$

$= 6+1 = 7$ (or)

$6-1 = 5$

$$\text{Coil pitch } Y = \frac{2C \pm 2m}{P/2}$$

m = 1 (for simplex)

$$\text{Then } Y = \frac{2\times 6 \pm 2\times 1}{2/2}$$

$= 12 \pm 2$

$= 12 + 2 = 14$ (or)

$12 - 2 = 10$

Front pitch $Y_f = Y - Y_b$

Also $Y_f = Y_b$

So $Y_f = 14 - 7 = 7$ (or)

$10 - 5 = 5$

Selected Y_b and Y_f are

$Y_b = Y_f = 7$ (or)

$(Y_f = Y_f = 5)$

Winding table (Y_f = Y_f = 5)

Sl. No.	$Y_b = 5$	$Y_f = 5$
1	1 – 6	6 – 11
2	11 – 4	4 – 9
3	9 – 2	2 – 7
4	7 – 12	12 – 5
5	5 – 10	10 – 3
6	3 – 8	8 – 1

In making winding table for wave winding, it is important that we must add back pitch and front pitch to obtain back end side and front end side respectively.

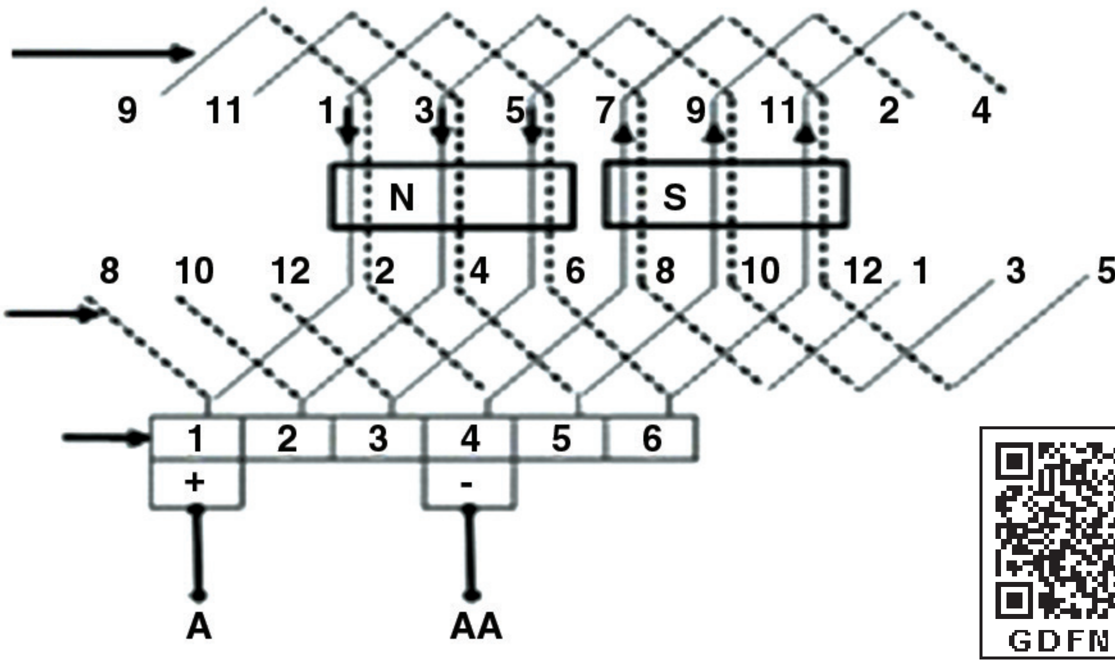


Fig. 9.11 2 Poles 6 slots simplex wave winding

9.6 AC windings

The winding made in the AC machines are called AC windings.

9.6.1 Types of AC windings

Generally three types of winding methods were carried out in AC machines. They are

i. Lap winding
ii. Wave winding and
iii. Concentric winding

9.6.2 Lap and wave winding

Lap windings are generally used in low voltage and high current electrical machines. But the wave windings are used in high voltage and low current electrical machines.

9.6.3 Concentric winding

The centre of all the coils in a coil group confined to a constant centre as shown in the figure 9.12 is called concentric winding.

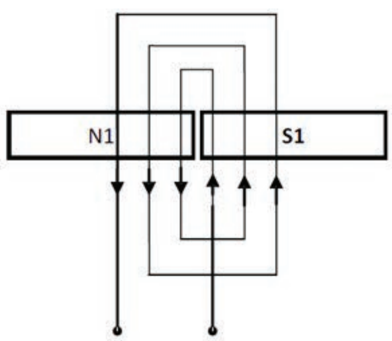


Fig. 9.12 Concentric winding

9.6.4 Coil group

Coil group consists of one coil or more than one coil connected in series.

When we carried out AC winding calculation, the number of coils per pole should be calculated. Then the coils in a pole should be separated for three phases also. Thus the coils per pole per phase is made into a coil group. By making coil groups, the number of end connections can be reduced and hence we can prevent short circuits in the end connection areas.

9.6.5 Pole pitch

It is the distance between the center of two adjacent poles. It is also denoted by the number of slots per pole.

$$\text{Pole pitch} = \frac{number\ of\ slots}{number\ of\ poles}$$

9.6.6 Winding pitch or coil pitch or coil span

It is the distance between the two coil sides of a coil.

Coil pitch = 1+ pole pitch

9.6.7 Full pitched winding

In full pitched winding, pole pitch and coil pitch are equal. There will be 180° (electrical degree) between the coil sides.

9.6.8 Fractional pitched winding

If we reduce or increase the coil pitch by one or two in number than the pole pitch, then it is called as fractional pitched winding. The angle (electrical degree) between the coil sides may be less than or more than 180°.

Fractional pitched winding may be divided into two types. They are

i. Short pitched winding (or) short chorded winding

ii. Long chorded winding

9.6.9 Pitch factor (K_c)

It is the ratio between the coil pitch and pole pitch. It is denoted by 'K_c'.

$$\text{Pitch factor, } K_c = \frac{coil\ pitch}{pole\ pitch} = cos\frac{\alpha}{2}$$

9.6.10 Short pitched winding or short chorded winding

If we reduce the coil pitch by one or two in number than the pole pitch, then it is called as short pitched winding. The reducing value should not exceed 1/3 rd of the pole pitch value. Electrical degree between two coil sides of short pitched winding will be less than 180°. This reduced angle is represented by short pitch angle (α). Here pitch factor will be less than one. This process reduces the weight of copper needed for winding the motors.

9.6.11 Long chorded winding

If we extend the coil pitch by one or two than the pole pitch, it is called as long chorded winding. Electrical degree between two coil sides of long chorded winding will be more than 180°. Here pitch factor will be more than one. This method of winding is rarely used.

9.6.12 Single layer winding

If each slot of a motor contains one coil side, then it is called single layer winding. Here the number of coils will be equal to the half of the total number of slots.

Hence,

$$\text{Number of coils} = \frac{\text{Total number of slots.}}{2}$$

9.6.13 Double layer winding

In double layer winding, two different coil sides of two coils are inserted in the same slot. Here the number of coils will be equal to the total number of slots.

Hence,

Number of coils = Total number of slots

9.6.14 Balanced winding

If the number of coils in all coil groups per phase are equal, then this type of winding is referred to as balanced winding.

9.6.15 Unbalanced winding

If the number of coils in all coil groups per phase are unequal, it is called unbalanced winding.

Do you Know?

Metal-Air batteries are small in size and have light weight batteries.

But its ranges are high. When not in use, they quickly disrupt.

Because metal electrodes are affected by corrosion.

9.6.16 Whole coil winding

If the number of coil groups per phase is equal to the number of poles, then the winding is called as whole coil winding. All the three phase lap windings and single phase concentric windings belong to this type.

9.6.17 Half coil winding

If the number of coil groups per phase is equal to the half of the number of poles, then the winding is called as half coil winding. This type of winding is used in three phase concentric winding.

9.6.18 Concentrated winding

If all the conductors of one coil side are inserted in single slot for making one complete pole or if we place a single coil for making one complete pole, it is called as concentrated winding.

Three phase half coil winding, field winding on pole of DC & AC generators are the examples of concentrated winding.

9.6.19 Distributed winding

Here the coils for a pole should not be made as a single coil and hence the pole contains several coils and inserted in several slots. This type of winding is known as distributed winding. All the stators and rotor windings of AC machines and armature winding of DC machines followed this type of winding.

9.6.20 AC single phase concentric winding

A.C, 1ϕ, 4 poles, 24 slots concentric winding for a split phase capacitor type motor.

$$\text{Pole pitch} = \frac{\textit{Number of slots}}{\textit{Number of poles}}$$

$$= \frac{24}{4}$$

$$= 6$$

Coil pitch = 1 + pole pitch

= 1+6 = 7

=1-7 (full pitched)

1-6 (short pitched)

For single phase concentric winding, we choose pole pitch as short pitch.

$$\text{Total no. of coils} = \frac{No\ of\ slots}{2}$$

(Single layer)

$$= \frac{24}{2}$$

$$= 12$$

$$\text{No. of coils per pole} = \frac{No\ of\ coils}{No\ of\ poles}$$

(coils / pole)

$$= \frac{12}{4}$$

$$= 3$$

$$\text{No. of coils per phase} = \frac{No\ of\ coils}{phases}$$

(coils / phase)

$$= \frac{12}{1}$$

$$= 12$$

No. of coils per pole per phase

$$= \frac{No\ of\ coils}{poles \times phases}$$

(coils / pole / phase)

$$= \frac{12}{4 \times 1}$$

$$= \frac{12}{4} = 3$$

Total no. of coil groups = poles × phases

= 4 x 1 = 4

No. of coils per coil groups

$$= \frac{No\ of\ coils}{No\ of\ coil\ groups}$$

(coils / coil group)

$$= \frac{12}{4}$$

$$= 3$$

Pole 1	Pole 2	Pole 3	Pole 4
3	3	3	3

K - calculation (No of slots for 90°)

Electrical degree for a slot

(or)

Electrical degree between adjacent slots

$$\beta = \frac{P \times 180°}{S}$$

$$= \frac{4 \times 180°}{24}$$

$$= \frac{720°}{24}$$

$$= 30°$$

$$\text{No of slots for } 90°\ (K) = \frac{90°}{30°} = 3$$

Hence,

Starting slot of the starting winding = 1st slot

Starting slot of the running winding = 1 + K

= 1 + 3

= 4th slot

So the starting winding must be inserted from the 1st slot and the running winding must be inserted from the 4th slot.

Winding table for starting coil

Phase	Poles			
	1	2	3	4
R	1 – 6	7 – 12	13 – 18	19 – 24
Y	3 – 8	9 – 14	15 – 20	21 – 26(2)
B	5 – 10	11 – 16	17 – 22	23 – 28(4)

Winding table for running coil

Phase	Poles			
	1	2	3	4
R	4 – 9	10 – 15	16 – 21	22 – 27(3)
Y	5 – 8	11 – 14	17 – 20	23 – 26(2)
B	6 – 7	12 – 13	18 – 19	24 – 25(1)

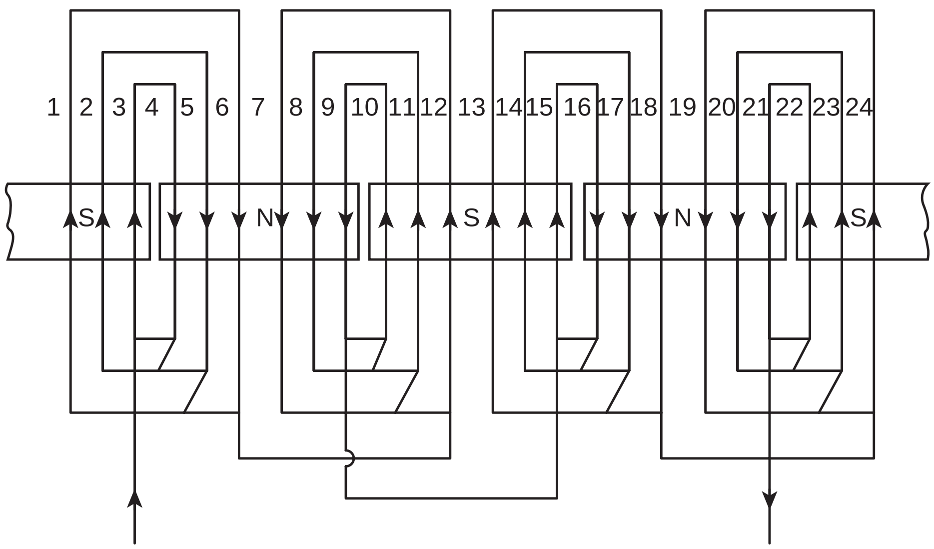


Fig. 9.13 1Ø, 4 Pole, 24 slots concentric starting winding diagram

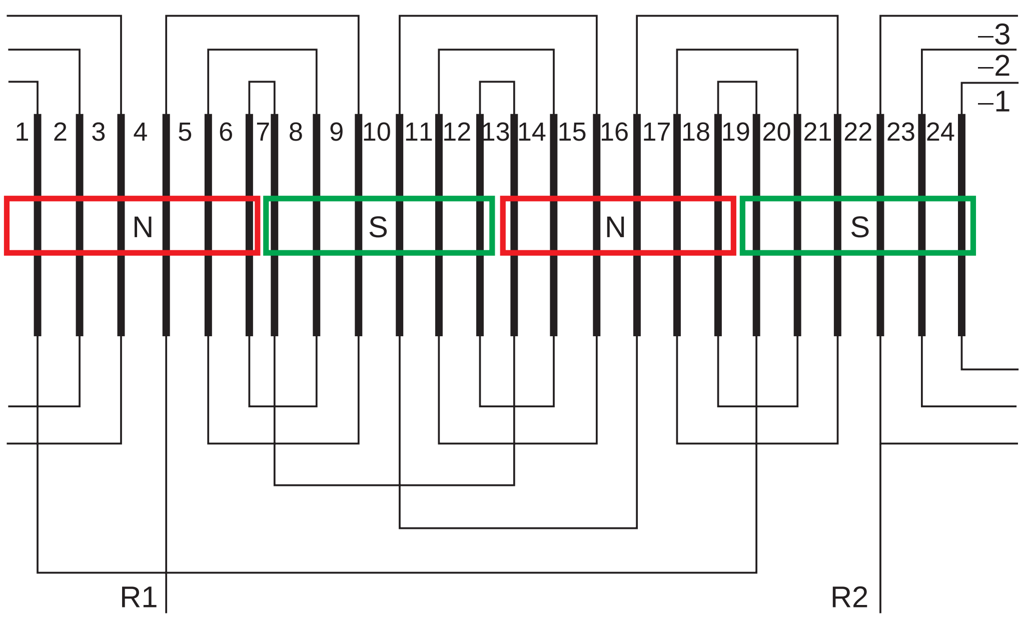


Fig. 9.14 1Ø, 4 Pole, 24 slots concentric running winding diagram

9.6.21 AC Three phase single layer lap Winding

AC, 1ϕ, 4 poles, 24 slots single layer lap winding diagram for an induction motor

$$\text{Pole pitch} = \frac{\textit{Number of slots}}{\textit{Number of poles}}$$

$$= \frac{24}{4}$$

$$= 6$$

Coil pitch = 1 + pole pitch

= 1 + 6 = 7

= 1-7 (full pitched)

1-6 (short pitched)

In single layer winding, successive coils must be placed by leaving one slot between them. Hence the left coil sides should be inserted in odd slots and the right coil sides should be inserted in even slots.

So, coil pitch = 1 – 8 (or)

= 1- 6

$$\text{Total no. of coils} = \frac{\textit{No. of slots}}{2}$$

(Single layer)

$$= \frac{24}{2}$$

$$= 12$$

$$\text{No. of coils per pole} = \frac{\textit{No. of coils}}{\textit{No. of poles}}$$

(coils / pole)

$$= \frac{12}{4}$$

$$= 3$$

$$\text{No of coils per phase} = \frac{\textit{No. of coils}}{\textit{phases}}$$

(coils / phase)

$$= \frac{12}{3}$$

$$= 4$$

No. of coils per pole per phase

$$= \frac{\textit{No. of coils}}{\textit{poles} \times \textit{phases}}$$

(coils / pole / phase)

$$= \frac{12}{4 \times 3}$$

$$= \frac{12}{12}$$

$$= 1$$

Because of the coils per pole per phase is a whole number, this winding is a balanced winding.

Total no. of coil groups = poles × phases

= 4 × 3 = 12

No. of coils per coil groups

$$= \frac{\textit{No. of coils}}{\textit{No of coil groups}}$$

(coils / coil group)

$$= \frac{12}{12}$$

$$= 1$$

Pole1			Pole2			Pole3			Pole4		
R	Y	B	R	Y	B	R	Y	B	R	Y	B
1	1	1	1	1	1	1	1	1	1	1	1

K - calculation (No of slots for 120°)

For a balanced winding,

$$\text{No of slots for } 120°, (K) = \frac{\textit{pole pitch}}{\textit{Phase}}$$

$$= \frac{6}{3} = 2$$

Hence,

Starting slot of 'R' phase = 1^{st} slot

Starting slot of 'Y' phase = 1 + K = 1 + 2

= 3^{rd} slot

Starting slot of 'B' phase = 3 + K = 3 + 2

= 5^{th} slot

Phase	Poles			
	1	2	3	4
R	1 – 6	7 – 12	13 – 18	19 – 24
Y	3 – 8	9 – 14	15 – 20	21 – 26(2)
B	5 –10	11 –16	17 – 22	23 – 28(4)

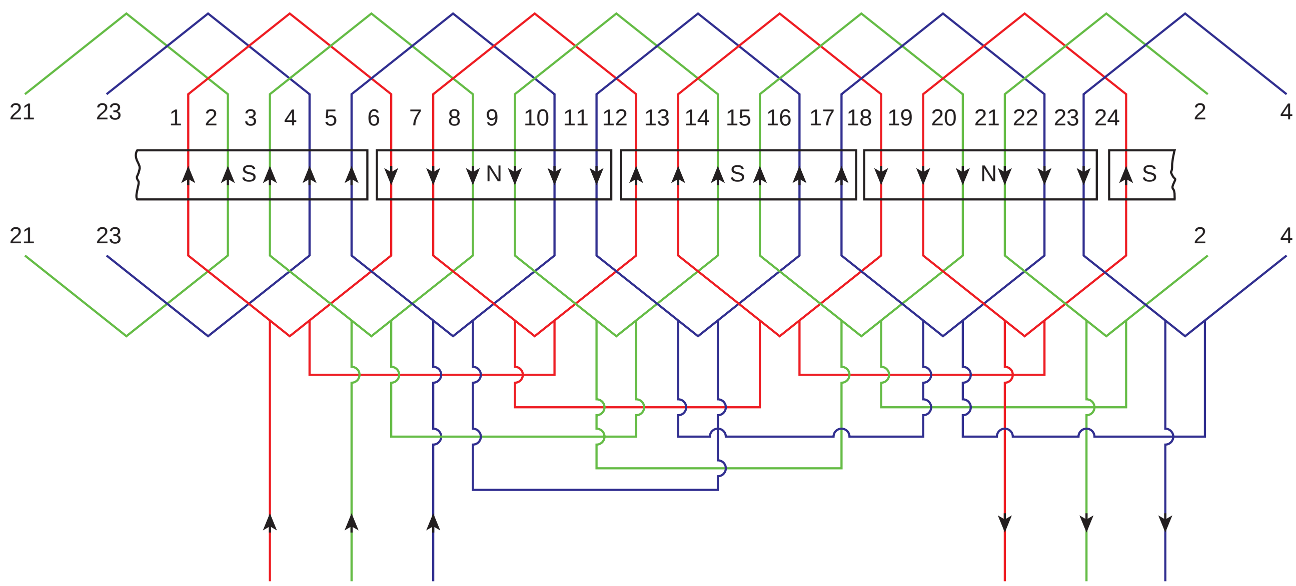


Fig. 9.15 Winding diagram for AC 3Ø induction motor, 4 pole 24 slots single layer lap winding

Glossary

Gauge number	-	கதவு எண்
Winding coil	-	உல்லைச் சுருள்
Phase	-	நிலை
Stator	-	நிலையி
Rotor	-	சுழலி
Armature	-	மின்னகம்

Evaluation

TA2I4B

PART - A

Choose the correct answer **(1 Marks)**

1. Heart of a motor is
   a) Stator
   b) Rotor
   c) Winding
   d) Bearings

2. The basic property needed for a good conductor is
   a) Low resistance
   b) High mechanical strength
   c) Best soldering property
   d) High dielectric strength

3. The diameter of the wire guage plate is generally
   a) 3 ¼ inches
   b) 3 ½ inches
   c) 3 ¾ inches
   d) 4 ¾ inches

4. The instrument used to measure the diameter of a conductor is
   a) Wire guage plate
   b) Feeler guage
   c) Dial guage
   d) Screw guage

5. Example for the liquid insulating material is
   a) Asbestos
   b) Varnish
   c) Glass
   d) Mercury

6. The winding placed in the rotating part of DC machine is
   a) Main field winding
   b) Armature winding
   c) Inter pole winding
   d) Compensating winding

7. The closed type of slots are used in
   a) Stators of small size motors
   b) Stators of medium size motors
   c) Stators of squirrel cage induction motors
   d) Rotors of squirrel cage induction motors

8. The value of back pitch will be
   a) Odd number
   b) Even number
   c) Fraction
   d) Decimal

9. The value of 'm' in simplex winding is
   a) 1
   b) 2
   c) 3
   d) 4

10. If a DC machine works as a motor, the law used to find the direction of flow of current in armature winding is
    a) Fleming's right hand rule
    b) End rule
    c) Fleming's left hand rule
    d) Ohm's law
11. The number of parallel paths of a DC lap winding is
    a) P/2
    b) 2P
    c) 2P
    d) 2
12. The number of parallel paths of a DC wave winding is
    a) P
    b) 2P
    c) P/2
    d) 2
13. The number of brushes in DC machines are
    a) Equal to the number of parallel paths.
    b) Equal to the number of slots.
    c) Equal to the half of the number of slots.
    d) Equal to the half of the number of poles.
14. The distance between two active sides of a coil in DC winding is
    a) Front pitch
    b) Coil pitch
    c) Back pitch
    d) Fractional pitch
15. The distance between the starting ends of two adjacent coil is
    a) Front pitch
    b) Back pitch
    c) Coil pitch
    d) Pole pitch
16. The type of winding used in DC armature is
    a) Main field winding
    b) Inter pole winding
    c) Open type winding
    d) Closed type winding
17. Pole pitch is referred to as
    a) The number of slots per pole
    b) The number of slots per phase
    c) The number of slots per pole per phase
    d) Half of the number of slots
18. In full pitched winding, the electrical degree between two coil sides of a coil is
    a) 60°
    b) 120°
    c) 180°
    d) 360°
19. The number of coils in single layer winding is
    a) Equal to the half of the number of slots
    b) Equal to the number of slots
    c) Equal to the half of the number of poles
    d) Equal to the number of poles

20. If the number of coils are equal to the number of slots, then the type of winding is
    a) Single slot winding
    b) Double slots winding
    c) Single layer winding
    d) Double layer winding

21. If the coil groups of a phase winding having unequal number of coils, then the winding is called as
    a) Half coil winding
    b) Whole coil winding
    c) Unbalanced winding
    d) Balanced winding

22. The number of coil groups in a phase of a full pitched winding is
    a) Equal to the number of poles
    b) Equal to the half of the number of poles
    c) Equal to the number of slots
    d) Equal to the half of the number of slots

PART-B

Answer the questions in brief (3 Marks)

1. What is the necessity of winding in motors?
2. What is conductor?
3. Mention the types to notify the size of the conductors and the instruments used to measure it.
4. With a neat diagram, explain the parts of a single turn coil.
5. What is lap winding?
6. What are the three types of windings used in AC machines?
7. What is concentric winding?
8. What is pole pitch?
9. Define pitch factor.
10. What is whole coil winding?

PART-C

Answer the questions in one page (5 Marks)

1. Draw the diagram of a gauge plate and explain the method of finding the guage number by it.
2. Explain the different type of pitches used in DC armature windings.
3. Explain the method of calculation for finding the number of coils and coil groups in AC winding.

PART-D

Answer the questions in two page **(10 Marks)**

1. Draw the double layer simplex lap winding diagram for a DC machine having 2 poles, 6 slots and 6 commutator segments. Also mention the brush positions.
2. Draw the simplex wave winding diagram for a DC machine having 2 poles, 6 slots and 6 commutator segments. Also indicate the position of brushes.
3. Develop the winding table for a single layer lap winding of a 4 poles, 24 slots, AC three phase induction motor.

Reference Book

1. A text book of 'Electrical Technology' Volume-III B.L.Theraja and A.K.Theraja, S.Chand & Company Ltd.

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2. https://www.electrical4u.com