ATME COLLEGE OF ENGINEERING

13th KM Stone, Bannur Road, Mysore - 570 028

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

NOTES

Course: Computer Aided Electric Drawing

Course Code: 21EE741

Semester: VII

Prepared by

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Department of EEE,

ATME College of Engineering

INSTITUTIONAL VISION AND MISSION

VISION:

- Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

MISSION:

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torchbearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

Department Vision and Mission

Vision:

To produce Electrical & Electronics Engineers through greatest quality of technical education, technical skill training and intellectual capacity building of individuals.

Mission:

- To provide knowledge to students that builds a strong foundation in the basic principles of electrical engineering, problem solving abilities, analytical skills, soft skills and communication skills for their overall development.
- To offer outcome based technical education.
- To encourage faculty in training & development and to offer consultancy through research & industry interaction.

Program Educational Objectives (PEOs)

PEO1:
To produce Electrical and Electronics Engineers who will exhibit the technical and managerial skills with professional ethics for the societal progress.

PEO2:

To make students continuously acquire, enhance their technical and socio-economic skills and also to be globally competent.

PEO3:

To impart the experience of research and development to students so that they develop abilities in offering solutions to relevant diverse career path.

PEO4:

To produce quality engineers with a team leading capabilities, also show good coordination to contribute towards real time application of projects

Program Outcomes (POs)

Engineering Graduates will be able to:

PO1: Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to the solution of complex engineering problems.

PO2: Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design / Development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

Graduates will develop the abilities to:

PSO1: Apply the concepts of Electrical & Electronics Engineering to evaluate the performance of power systems and also to control industrial drives using power electronics.

PSO2: Demonstrate the concepts of process control for Industrial Automation, design models for environmental and social concerns and also exhibit continuous self- learning.

Department of Electrical and Electronics Engineering

Computer Aided Electrical Drawing

Module-1
Winding Diagrams:
(a) Developed Winding Diagrams of D.C. Machines: Simplex Double Layer Lap and Wave Windings.
(b) Developed Winding Diagrams of A.C. Machines:
(c)Integral and Fractional Slot Double Layer Three Phase Lap and Wave Windings.
(d) Single Layer Windings – Un-Bifurcated 2 and 3 Tier Windings, Mush Windings, Bifurcated 3 Tier Windings2. Single line diagrams of generating stations and substations.

Module-2:

Single Line Diagrams: Single Line Diagrams of Generating Stations and Substations Covering Incoming Circuits, Outgoing Circuits, Busbar Arrangements (Single, Sectionalised Single, Main and Transfer, Double Bus Double Breaker, Sectionalised Double Bus, One and a Half Circuit Breaker Arrangement, Ring Main),Power Transformers, Circuit Breakers, Isolators,Earthing Switches,Instrument Transformers, Surge or Lightning Arresters, Communication Devices (Power-Line Carrier) and Line Trap

Module-3:

Electrical Machine Assembly Drawings Using Design Data, Sketches or Both:
Transformers - Sectional Views Of Single And Three Phase Core And Shell Type Transformers .

Module-4:

Electrical Machine Assembly Drawings Using Design Data, Sketches or Both:
D.C. Machine - Sectional Views of Yoke with Poles, Armature and Commutator dealt separately.

Module-5:
Electrical Machine Assembly Drawings Using Design Data, Sketches or Both:
Alternator – Sectional Views of Stator and Rotor dealt separately

Department of Electrical and Electronics Engineering

Module-1

DC WINDING DIAGRAM

Objective : To draw the developed winding diagram and sequence diagram of DC machines

Procedure for Lap Winding:

1. Pitch calculation

Sequence of steps involved	Symbol	Remarks
Number of slots in the armature	N1	
Number of coil sides per slots	M	
Number of Poles	P	
Total number of conductors	Z=N1*m	
Pole Pitch in terms of conductors	Y_p=Z/P	
Modified integer value of the pole pitch	Y_p	If the value is a fraction choose an integer lower than the obtained fractional figure.
Commutator Pitch	Y_c=X	X: 1 Simplex; 2 Duplex; 3 Triplex; 4 Quadraplex
Back Pitch(Unmodified) Front Pitch(Unmodified)	Y_b Y_f	The values are obtained by solving the two equations $Y_b + Y_f = 2Y_p$ $Y_b - Y_f = +-2Y_c$ +for progressive lap winding _ for retrogressive winding
Final Back Pitch Final Front Pitch	Y_b Y_f	If the values of Y_b and Y_f are even, then select the next lower values of odd integers for both Y_b and Y_f

2. The winding table is prepared.
3. The drawing is made for the developed lap winding, using the winding table.
4. The position of poles, current directions, brushes are shown in the winding diagram.

Department of Electrical and Electronics Engineering

Procedure for Wave Winding:

1. Pitch calculation

Sequence of steps involved	Symbol	Remarks
Number of slots in the armature	N1	
Number of coil sides per slots	M	
Number of Poles	P	
Total number of conductors	Z=N1*m	
Pole Pitch in terms of slots	Y_{ps} =Z/P	
Commutator Pitch	Y_c=(Z+_2X)/P '+' for progressive wave winding '-' for retrogressive wave winding	X: 1 Simplex; 2 Duplex; 3 Triplex; 4 Quadraplex
Back Pitch Front Pitch	Y_b Y_f	Choose Y_b and Y_f such that i)They are odd numbers ii) Y_b+ Y_f =2Y_c iii) The values are neare to Y_{ps}

2. The winding table is prepared.
3. The drawing is made for the developed lap winding, using the winding table.
4. The position of poles, current directions, brushes are shown in the winding diagram.

Example 1:

Develop a <u>single layer</u> winding for a Dc machine having 32 armature conductors and 4 poles. Mark the poles. Draw the sequence diagram. Indicate the position of the brushes. Show the direction of induced emf and give equalizer connections.

Solution:

No. of poles=4

Total number of conductors, Z=32 (Single layer)

Pole pitch=Z/P=32/4=8

We have: (Y_b+ Y_f)/2 = Pole Pitch

Therefore (Y_b+ Y_f)/2 = 7.5

$Y_b + Y_f = 16$…..... (1)

$Y_b - Y_f = 2$…..... (2)

By solving above equations (1) & (2), We get $Y_b=9$, $Y_f = 7$

For lap winding Y_b&Y_f should be odd and differ by two. For satisfying the condition, we can take $Y_b=9$, $Y_f = 7$

Steps for drawing the winding diagram:

Step 1:

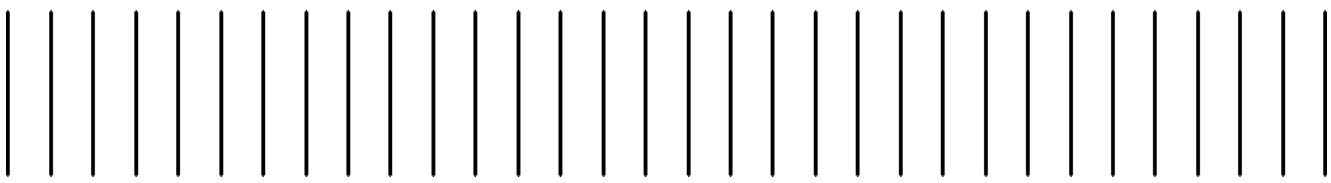
- Start with a new file
- Set the limits. Type limits at the command prompt, keep the lower left corner at 0,0i,e type 0,0 and enter, type 297,210 for the upper right corner
- Type zoom and enter, all and enter

Step 2:

Create a line:

- Type line and press enter at the command user interface
- Specify a start point of the line any where
- On the screen with ORTHO status bar in ON state as shown below.

- Similarly 32 conductors can be drawn or obtained by using ARRAY command. Type Array in command line or click array icon
- Select the line to be arrayed by crossing method and press enter
- Specify opposite corner for no. of items or count: Type'c' in command line and press enter
- Enter the no. of rows:1 and press enter
- Enter the no. of columns: 32 and press enter
- Specify opposite corner to space items or <spacing>:20
- Double click on the object and re-enter the spacing as 20
- The result is as shown

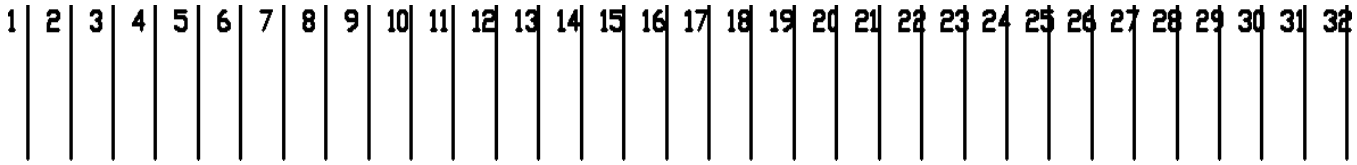


Step 3:

Creating the text:

- Type text at the command user interface or go to draw, select text, select single line text

- Select the starting point from where the text is to be started
- Specify the height of the text as 2.5mm
- Specify the rotation angle for the text as 0
- Type the text, which is to be displayed and enter twice or press Esc to come out of the text command
  Or
  Select the text icon and drag it over the conductors and type the conductor numbers providing the spacing between the numbers and press ok



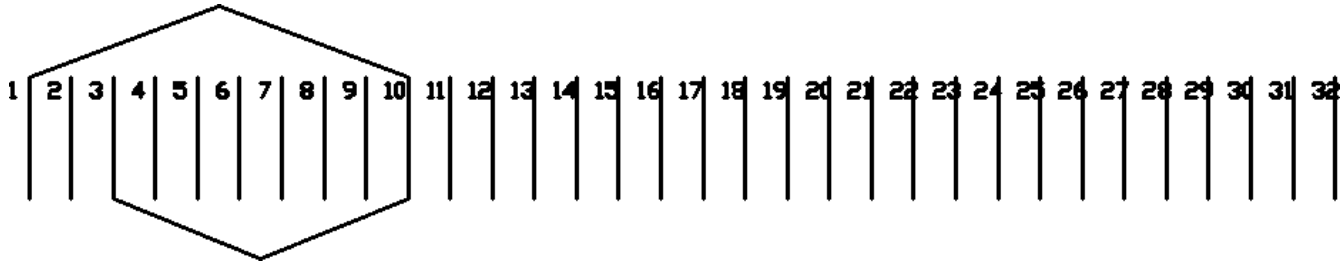
Step 4:

Winding table:

At the back Y_b=9		At the front Y_f=7	
Coil side	Connected coil side	Coil side	Connected coil side
1+9=10		10-7=3	
3+9=12		12-7=5	
5+9=14		14-7=7	
7+9=16		16-7=9	
9+9=18		18-7=11	
11+9=20		20-7=13	
13+9=22		22-7=15	
15+9=24		24-7=17	
17+9=26		26-7=19	
19+9=28		28-7=21	
21+9=30		30-7=23	
23+9=32		32-7=25	
25+9=34(2)		34-7=27	
27+9=36(4)		36-7=29	
29+9=38(6)		38-7=31	
31+9=40(8)		40-7=33(1)	

Form a loop:

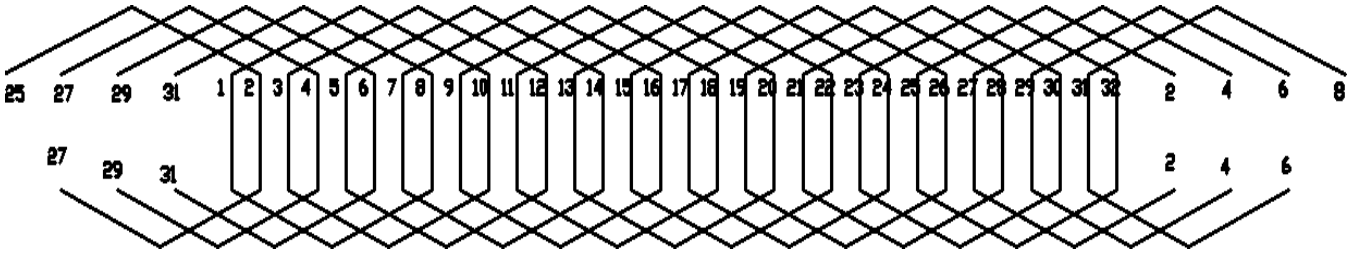
- Use the data from winding table
- Keep ORTHO in off state and OSNAP in On state. Select end point and midpoint in the OSNAP property
- Type line in command user interface and form a loop as shown in the diagram below



Step 5:

Copy the entire loop or array the entire loop:

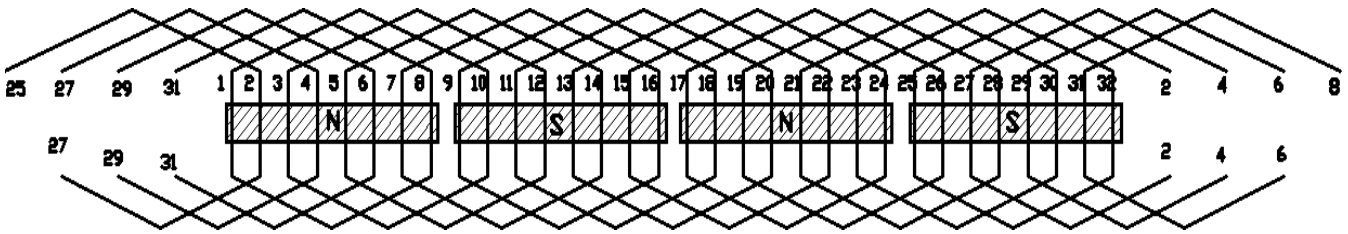
- Type copy at the command user interface.
- Select the entire loop or a coil either by window or crossing method
- Specify the base point, base point of displacement multiple as m[for multiple copy] copy the coil or loop as shown
- To array: select rectangular array>> no of rows = 1>> no of columns = 16>> column offset = 40 >> select object >> OK



Step 6:

Creating the poles:

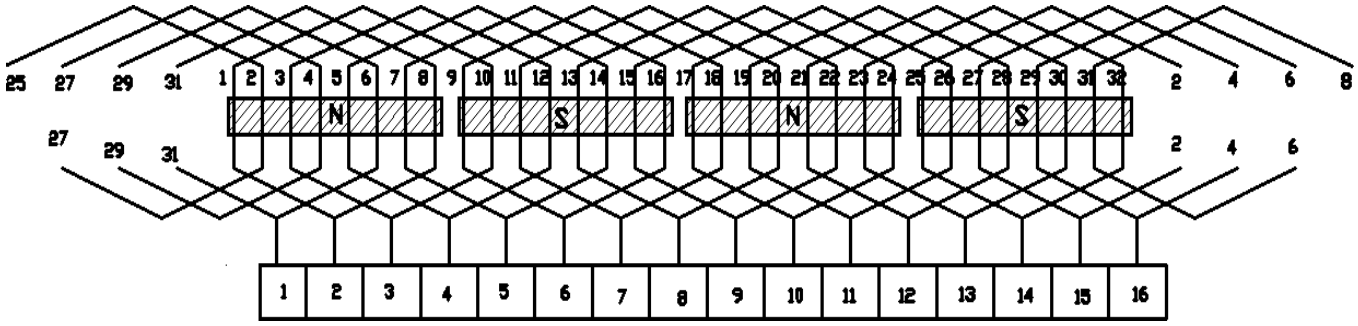
- Type rectangle or rec at the command user interface or select rectangle icon
- Specify first corner point, i.e. click at the desired location by referring the drawing
- Specify the other corner point, i.e. click at the diagonally opposite point
- Crate the text i.e. N & S in the same way as explained above



Step 7:

Creating the commutator segments

- Type line in the command user interface
- Draw the first one commutator segment
- Array the segments in the same way as explained above.(or) Copy and place the commuator segments keeping ortho mode ‘ON’ The result is as shown in the fig.
- Create the text, i.e. 1 to 16 in the same way as explained early



Step 8:

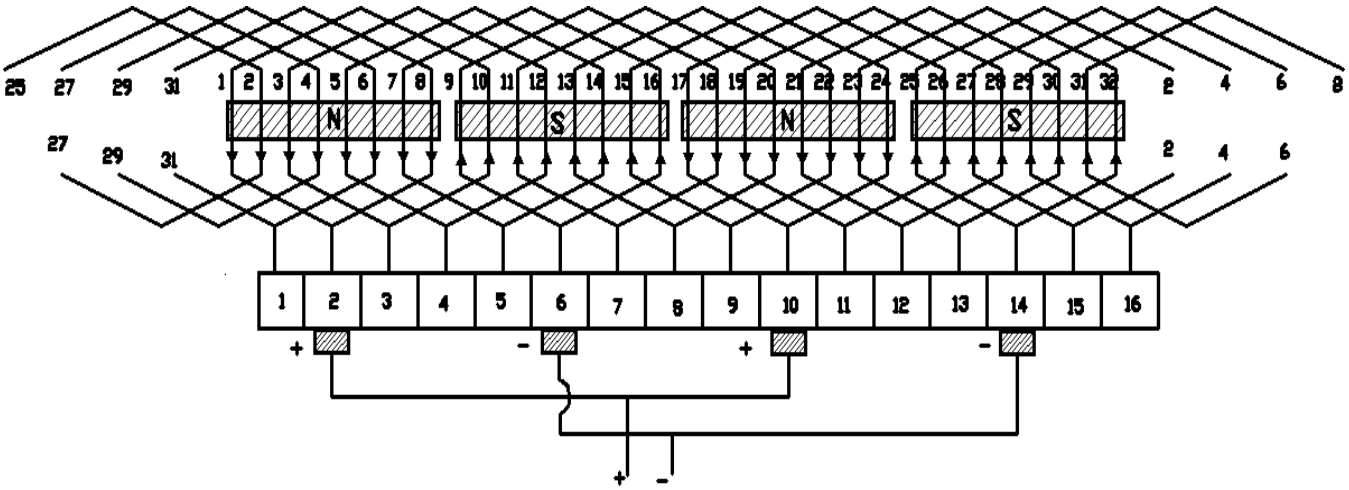
Creating a brush:

- Type rectangle or rec at the command user interface
- Move the rectangle below the commutator segment
- Type hatch pattern from the swatch button, select an appropriate scale and click inside the area to be hatch and click ok

Step 9:

Crating the directional arrows:

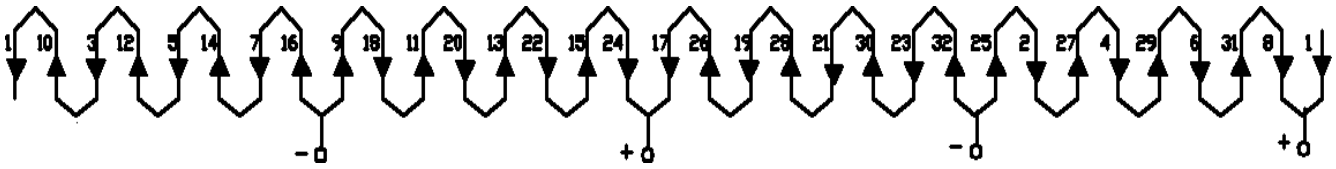
- Type polyline at the command user interface
- Specify the starting point of the arrow
- Type hatch or h at the command user interface. Select the hatch pattern form the swatch button [i.e. select solid]. Select the object in which solid is to be filled and later click ok the result is as below.



- This arrow can be reverse by using rotate command
- Move the arrow and place on the conductor
- Using copy tool bar, copy the arrows as per the drawing.

Step 11:
Creating sequence diagram:

- Using step 2 to 5 and step 10 sequence diagram can be drawn.



Example 2:

Design and draw 4 pole <u>wave winding (progressive)</u> for an armature with 34 conductors accommodated 17 slots, show position of brush, direction of current.

Solution:

No. of poles P= 4; No. of slots=17

No. of conductors=34(double layer)

In wave winding $Y_b$and $Y_f$can be calculated from the following formulae

$(Y_b + Y_f)/2 = (Z+-2)/P$

$(Y_b + Y_f)/2 = (34+2)/4$…… (**For progressive winding +)**

$Y_b + Y_f = 18$ taking $Y_b = Y_f$

Hence $Y_b = 9$ and $Y_f = 9$

Steps for drawing the winding diagram:

Step 1:

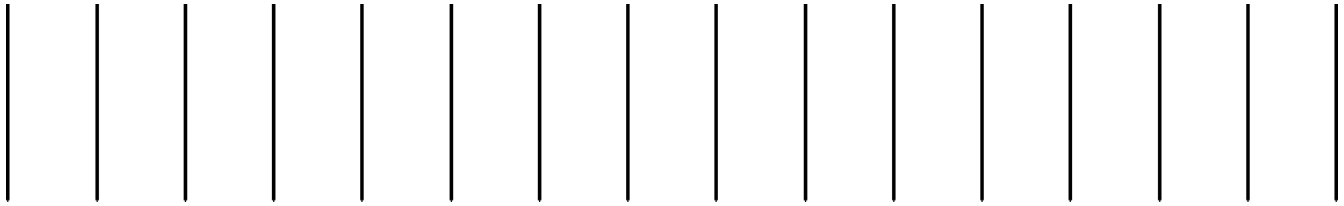
- Start with a new file
- Set the limits. Type limits at the command prompt, keep the lower left corner at 0,0i,e type 0,0 and enter, type 297,210 for the upper right corner
- Type zoom and enter, all and enter

Step 2:

Create a line;

- Type line and press enter at the command user interface
- Specify a start point of the line any where
- On the screen with ORTHO status bar in ON state as shown below.

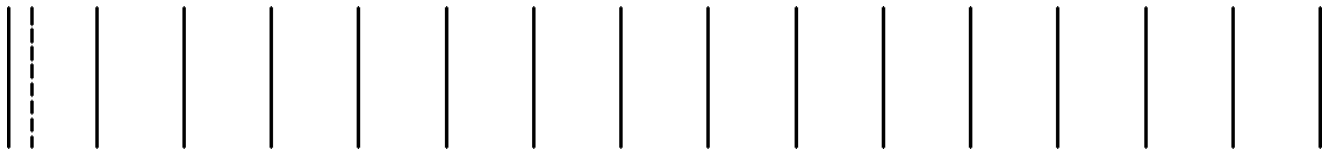
- Similarly 17 slots can be drawn or obtained by using ARRAY command. Type Array in command line or click array icon
- Select the line to be arrayed by crossing method
- Specify the no. of rows=4
- Specify the no. of columns=17
- Specify the distance between the column as 40, then press ok or enter key. The result is as shown



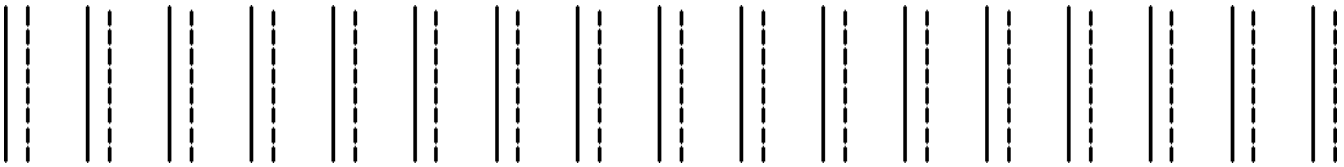
Step 3:

To obtain dotted lines:

- Click By layer icon
- Select load
- Select the dotted line and click ok
- Then draw the second conductor of the slot and later array it using above procedure, result is as follows.



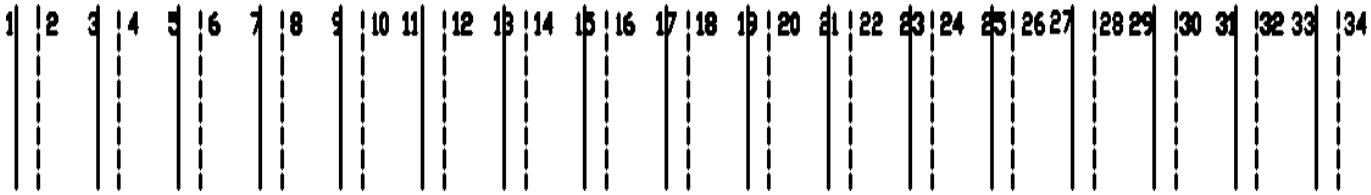
- After array we get,



Step 4:

Creating the text:

- Type text at the command user interface or go to draw, select text, select single line text
- Select the starting point from where the text is to be started
- Specify the height of the text as 2.5mm
- Specify the rotation angle for the text as 0
- Type the text, which is to be displayed and enter twice or press Esc to come out of the text command
- Or , use text icon to number the conductors



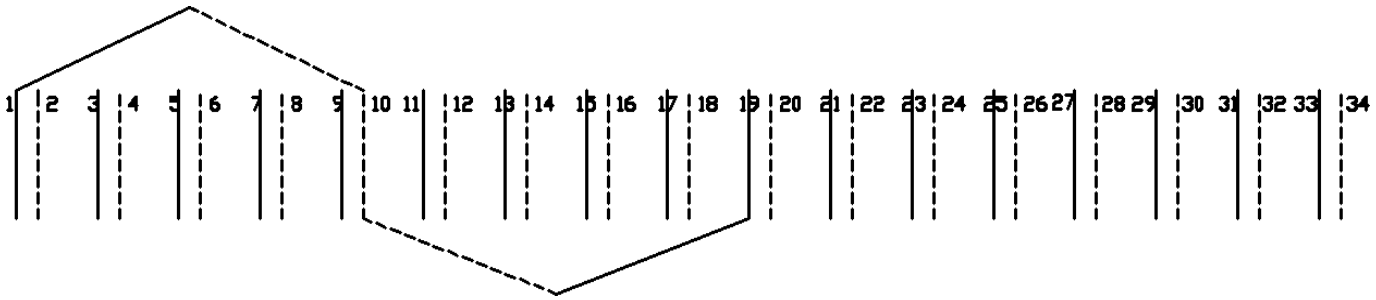
Step 5:

Winding table:

At the back Coil side Connected coil side	At the front Coil side Connected coil side
1+9=10	10+9=19
19+9=28	28+9=37(3)
3+9=12	12+9=21
21+9=30	30+9=39(5)
5+9=14	14+9=23
23+9=32	32+9=41(7)
7+9=16	16+9=25
25+9=34	34+9=43(9)
9+9=18	18+9=27
27+9=36(2)	2+9=11
11+9=20	20+9=29
29+9=38(4)	4+9=13
13+9=22	22+9=31
31+9=40(6)	24+9=33
15+9=24	6+9=15
33+9=42(8)	8+9=17
17+9=26	26+9=35(1)

Form a loop:

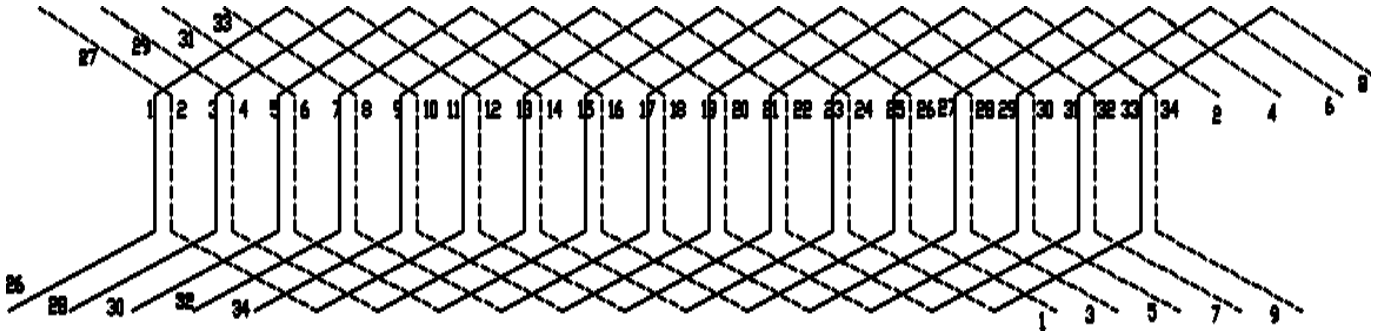
- Use the data from winding table
- Keep ORTHO in off state and OSNAP in On state. Select end point and midpoint in the OSNAP property
- Type line in command user interface and form a loop as shown in the diagram below



Step 6:

Array the entire loop:

- Rectangular array>> no of rows=1 >>no of column= 17 >>column offset= 40 .
- To copy the loop on left side where the loop is not arrayed, Select the entire loop or a coil either by window or crossing method
- Specify the base point, base point of displacement multiple as m[for multiple copy] copy the coil or loop as shown



Step 7:

Creating the poles:

- Type rectangle or rec at the command user interface
- Specify first corner point, i.e. click at the desired location by referring the drawing
- Specify the other corner point, i.e. click at the diagonally opposite point
- Crate the text i.e. N & S in the same way as explained above

Step 8:

Creating the commutator segments

- Type line in the command user interface
- Draw the first one commutator segment
- Array the segments in the same way as explained above. The result is as shown below
- Create the text, i.e. 1 to 17 in the same way as explained early

Step 9:

Creating a brush:

- Type rectangle or rec at the command user interface

- Move the rectangle below the commutator segment
- Type hatch pattern from the swatch button, select an appropriate scale and click inside the area to be hatch and click ok

Step 10:

Crating the directional arrows:

- Type polyline at the command user interface
- Specify the starting point of the arrow
- Type hatch or h at the command user interface. Select the hatch pattern form the swatch button [i.e. select solid]. Select the object in which solid is to be filled and later click ok the result is as below
- This arrow can be reverse by using rotate command
- Move the arrow and place on the conductor
- Using copy tool bar, copy the arrows as per the drawing.

Step 11:

Creating sequence diagram:

- Using step 2 to 5 and step 10 sequence diagram can be drawn.

Example 3:

Draw the simplex retrogressive wave winding with 4 pole DC machine having 42 armature conductors. The winding is single layer. Fix the position of poles, direction of current mark the position of brushes for equivalent ring diagram.

Solution:

No. of poles P=4
No. of conductors Z=42(Single layer)
In wave winding $Y_b$and $Y_f$can be calculated from the following formulae

$(Y_b + Y_f)/2 = (Z+-2)/P$

$(Y_b + Y_f)/2 = (42-2)/4$…… (**For retrogressive winding -)**

$Y_b + Y_f = 20$ …… (1)

$Y_b - Y_f = 2$..... (2)

By solving equation (1) & (2) we get,

Y_b= 11 and Y_f= 9

Winding Table:

At the back Coil side Connected coil side	At the front Coil side Connected coil side
1+11=12	12+9=21
21+11=32	32+9-41
41+11=52(10)	10+9=19
19+11=30	30+9=39
39+11=50(8)	8+9=17
17+11=28	28+9=37
37+11=48(6)	6+9=15
15+11=26	26+9=35
35+11=46(4)	4+9=13
13+11=24	24+9=33
33=11=44(2)	2+9=11
11+11=22	22+9=31
31+11=42	42+9=51(9)
9+11=20	20+9=29
29+11=40	40+9=49(7)
7+11=18	18+9=27
27+11=38	38+9=47(5)
5+11=16	16+9=25
25+11=36	36+9=45(3)
3+11=14	14+9=23
23+11=34	34+9=43(1)

Steps for drawing the winding diagram:

Command	Details
Units	Mm
Limits	Lower left: 0,0 Upper right: 297,210
Zoom, all	
Line	Specify first point: any where Specify next point or [undo]: @40<270 Specify next point: press enter key Top conductor is formed
Line Bylayer Line type	Select: Bylayer Select: Others, Select: Load, Select: Dashed Select: Global scale=1, press ok Select: Bylayer Dashed Command: Line First point: 20,130 Second Point: @40<270

	Broken line for bottom conductor is formed
Array	Rectangular Rows:1,Column: 21, Row offset:0, column offset:20 Select objects: Select top and bottom conductors Multiple conductors using array
Text	➢ Type text at the command user interface or go to draw, select text , select single line text ➢ Select the starting point from where the text is to be started ➢ Specify the height of the text as 3mm ➢ Specify the rotation angle for the text as '0' ➢ Type the text, which is to be displayed and enter twice or press 'Esc' to come out of the text command ➢ Array the text i.e. 1 throughout the 42 conductors ➢ To change the text number from 1 to 42 ➢ Select the text number by double click you want to change and type the text number and click ok
Line	Make end connection by joining top conductor 1 and bottom conductor 8 in the back side and conductor 8 and 3 in the front side i.e. commutator side, One complete end connection is formed.
Array	Rows: 1, Column: 21, Row offset; 0, Column offset: 20 Select objects: select above end connections
Array	Rows: 1, columns; 4, Row offset: 0, Column offset: -20 Select objects: select below end connections All end connections are formed.
Trim	Trim extra portions of conductors
Line	To draw commutator segments ➢ Type line in the command user interface ➢ Draw the first one commutator segment ➢ Array the segments in the same way as explained above ➢ Create the text i.e. 1 to 21 in the same way as explained early.
Rectangle, copy	Draw poles and brushes
Hatch	Fill poles and brushes with patterns using hatch command. Type predefined, pattern: ANS131, Scale:1, Angle:0 Add select objects: Select rectangle representing N poles and + brushes. Fill S pole and – brushes with same pattern and angle=90
Polyline, Array/Copy, Mirror/Rotate	Create one down arrow using polyline Start point: Select the start point of the arrow, Next point: w Starting width: 3, Ending width; 0 Next point: @5<270 Draw arrows to all conductors to show current directions
Line, Text	Make end connections and mark the terminals
Text	Give heading

Example 4:

Draw the armature winding of a DC machine with 4 poles, 14 slots, double layer progressive lap. Show the position of brush and direction of induced emf

Solution:

No. of poles=4

No. of slots=14

Total number of conductors, Z=28 (Double layer)

Pole pitch=Z/P=30/4=7

We have: $(Y_b + Y_f)/2$ = Pole Pitch

Therefore $(Y_b + Y_f)/2 = 7$

$Y_b + Y_f = 14$…..... (1)

$Y_b - Y_f = 2$…..... (2)

By solving above equations (1) & (2), We get $Y_b=8$, $Y_f = 6$

For lap winding Y_b&Y_f should be odd and differ by two. For satisfying the condition, we can take $Y_b=7$, $Y_f = 5$

Winding Table:

At the back $Y_b=7$		At the front $Y_f=5$	
Coil side	Connected coil side	Coil side	Connected coil side
1+7=8		8-5=3	
3+7=10		10-5=5	
5+7=12		12-5=7	
7+7=14		14-5=9	
9+7=16		16-5=11	
11+7=18		18-5=13	
13+7=20		20-5=15	
15+7=22		22-5=17	
17+7=24		24-5=19	
19+7=26		26-5=21	
21+7=28		28-5=23	
23+7=30		30-5=25	
25+7=32(2)		32-5=27	
27+7=34(4)		34-5=29	

Steps for drawing the winding diagram:

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Command	Details
Units	Mm
Limits	Lower left: 0,0 Upper right: 297,210
Zoom, all	
Line	Specify first point: any where Specify next point or [undo]: @40<270 Specify next point: press enter key Top conductor is formed
Line Bylayer Line type	Select: Bylayer Select: Others, Select: Load, Select: Dashed Select: Global scale=1, press ok Select: Bylayer Dashed Command: Line First point: 40,130 Second Point: @40<270 Broken line for bottom conductor is formed
Array	Rectangular Rows:1,Column: 14, Row offset:0, column offset:20 Select objects: Select top and bottom conductors Multiple conductors using array
Text	➢ Type text at the command user interface or go to draw, select text , select single line text ➢ Select the starting point from where the text is to be started ➢ Specify the height of the text as 3mm ➢ Specify the rotation angle for the text as '0' ➢ Type the text, which is to be displayed and enter twice or press 'Esc' to come out of the text command ➢ Array the text i.e. 1 throughout the 30 conductors ➢ To change the text number from 1 to 30 ➢ Select the text number by double click you want to change and type the text number and click ok
Line	Make end connection by joining top conductor 1 and bottom conductor 8 in the back side and conductor 8 and 3 in the front side i.e. commutator side, One complete end connection is formed.
Array	Rows: 1, Column: 15, Row offset; 0, Column offset: 20 Select objects: select above end connections
Array	Rows: 1, columns; 4, Row offset: 0, Column offset: -20 Select objects: select below end connections All end connections are formed.
Trim	Trim extra portions of conductors
Line	To draw commutator segments ➢ Type line in the command user interface ➢ Draw the first one commutator segment ➢ Array the segments in the same way as explained above ➢ Create the text i.e. 1 to 14 in the same way as explained early.
Rectangle, copy	Draw poles and brushes

Hatch	Fill poles and brushes with patterns using hatch command. Type predefined, pattern: ANS131, Scale:1, Angle:0 Add select objects: Select rectangle representing N poles and + brushes. Fill S pole and – brushes with same pattern and angle=90
Polyline, Array/Copy, Mirror/Rotate	Create one down arrow using polyline Start point: Select the start point of the arrow, Next point: w Starting width: 3, Ending width; 0 Next point: @5<270 Draw arrows to all conductors to show current directions
Line, Text	Make end connections and mark the terminals
Text	Give heading

Outcome: Students will be able to draw the developed winding diagram and sequence diagram of DC machines for given number of conductors.

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THREE PHASE A.C.WINDING

Objective :

- To draw the Integral and Fractional slot double layer Lap and Wave winding diagram for ac machines
- To draw the Single layer windings – Un-bifurcated 2 and 3 tier windings, mush windings, Bifurcated 2 and 3 tier windings

INTRODUCTION

- The armature windings of a.c machine may be closed giving delta connections or open resulting in star connection.
- Windings must be designed such that it should induce emf which is sinusoidal in nature.
- Winding can be single layer or double layer.

ARMATURE WINDING TERMS

- **Pole pitch-** it is defined as number of slots per pole.
- **Slots/pole/phase -** it is number of armature slots coming under one pole for one phase.

  M=slots/p*phase , where p is no of poles
- **Slot Angle (β)-**it is the angle between induced emfs in the coils placed in consecutive armature slots.

(β)=180/slots per pole in degrees

Full pitched winding- when a coil formed by two coil sides are spaced exactly equal to one pole pitch (180^0 electrical) then it is known as full pitched winding.

- **Short pitched winding-** when the distance between two coil sides is less than one pole pitch ($< 180^0$ electrical) such winding is known as short pitched winding.
- **Pitch factor (coil span factor)-** it is the factor by which magnitude of induced emf is less due to short pitched winding.
- **Pitch factor ,** $K_p=\cos(n\alpha/2)$
- ά- angle by which winding is short pitched
- n- order of harmonic to be eliminated

PHASE SPREAD

- Distribution of each phase coil in the armature slots to obtain phase difference of 120^0 between the start of each windings is known as phase spread
- For a phase sequence of R-Y-B , phase spread can be of
- 120^0 phase spread or wide spread winding
- 60^0 phase spread or narrow spread winding
- In 120^0 phase spread winding, each phase coils under a pole occupies a space of 120^0 ele, thus for phase sequence of RYB, phase spread is RYB.
- In 60^0 phase spread winding, each phase coils occupy a space of 60^0 ele, thus for phase sequence of RYB, phase spread is RBY.

INTEGRAL SLOT LAP WINDING

- 1) Draw the developed winding diagram of a 3 phase delta connected synchronous machine, having 12 slots,4 poles. The winding details are as given below

i. Type of winding-double layer, full pitched,lap

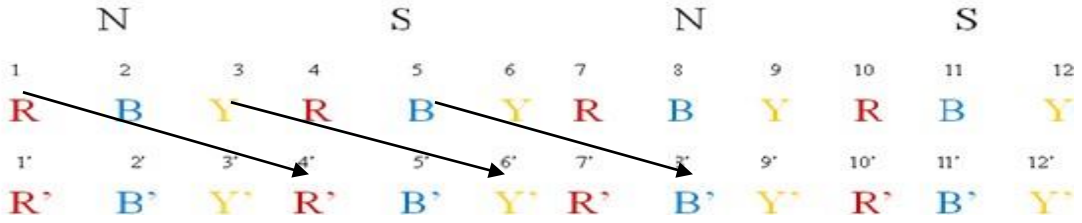
ii. Phase sequence-RYB

Phase spread-RBY

- Pole pitch=S/P=12/4=3
- m=(S/P)/phase=(12/4)/3=1 (Integral slot)
- No. of conductors, Z=Sx2=24 (Double Layer)
- Slot angle, $\beta=(180^0)/(S/P)=(180^0)/(12/4)=60^0$
- Let start of R phase be slot number 1, $S_R=1^{st}$ slot
- Thus, start of Y phase is given by $S_Y=1+(120^0/\beta)=1+(120^0/60^0)=3^{rd}$ slot, and

  $S_B=1+(240^0/60^0)=5^{th}$ slot

- For a 60^0 phase spread, the slot distribution table is as shown



Steps for drawing the winding diagram:

Command	**Details**
Units	Mm
Limits	(0,0) (1000,1000)
Zoom, All	
Line	First Point: 20,150 Next Point: @40<270 Press Enter
By Layer	Select By Layer Option Load:Dashed, Set Global Factor:1
Broken Line	Select Dashed Line which is formed in the above step First Point:25,150 Second Point: @40<270 Broken Line for bottom conductor is formed
Array	Rectangular Columns: 24 Row: 1 Column Offset:10
Text	Specify first & opp corner whereever text required Type the text Press OK Array the text written to 24 conductors and edit it.[1, 2,….....24]
Line	Make end connections by joining top conductor 1 and bottom conductor 4

Array	Rectangular Columns: 24 Row: 1 Column Offset:10 Select object: the above end connection
Array	Rectangular Columns: 4 Row: 1 Column Offset:-10
Trim	Trim unnecessary connections at the beginning and end of the winding
By Layer	Color the coils by choosing by layer option or by Match properties
Mirror	Select object: All end conductors Base: mid point of all conductors
Line Trim	Join all the three coil group sets with two connectors for the bottom connection side.
Line Trim Circle	Use " End to End" and "Start to Start" pattern and connect all the coil groups
Line Copy	Mark the arrow heads for defining poles
Text	Mark R1, R2, Y1, Y2, B1,B2

INTEGRAL SLOT WAVE WINDING

- 1) Draw the developed winding diagram of a 3 phase delta connected synchronous machine, having 24 slots,4 poles. The winding details are as given below

i. Type of winding-double layer, full pitched, wave

ii. Phase sequence-RYB

iii. Phase spread-RBY

SOLUTION

- Pole pitch=S/P=24/4=6
- m=(S/P)/phase=(24/4)/3=2 (Integral slot)
- No. of conductors, Z=Sx2=48 (Double Layer)

- Slot angle, $\beta=(180^0)/(S/P)=(180^0)/(24/4)=30^0$
  - Let start of R phase be slot number 1, $S_R=1^{st}$ slot

- Thus, start of Y phase is given by $S_Y=1+(120^0/\beta)=1+(120^0/30^0)=5^{th}$ slot, and

  $S_B=1+(240^0/30^0)=9^{th}$ slot

- For a 60^0 phase spread, the slot distribution table is as shown

N S N S

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24

R R B B Y Y R R B B Y Y R R B B Y Y R R B B Y Y

R' R' B' B' Y' Y' R' R' B' B' Y' Y' R' R' B' B' Y' Y' R' R' B' B' Y' Y'

Steps for drawing the winding diagram:

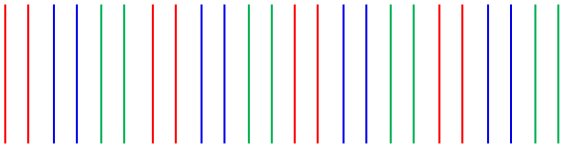
Command	**Details**
Units	Mm
Limits	(0,0) (1000,1000)
Zoom, All	
Line	First Point: 20,150 Next Point: @40<270 Press Enter
By Layer	Select By Layer Option Load:Dashed, Set Global Factor:1
Broken Line	Select Dashed Line which is formed in the above step First Point:25,150 Second Point: @40<270 Broken Line for bottom conductor is formed
Array	Rectangular Columns: 48 Row: 1 Column Offset:10
Text	Specify first & opp corner whereever text required

	Type the text Press OK Array the text written.
Line	Connect the R phase coils from slot 1, Y phase coils from slot 5, B phase coils from slot 9
Array	Rectangular Columns: 24 Row: 1 Column Offset:10 Select object: the above end connection
Array	Rectangular Columns: 8 Row: 1 Column Offset:-10
Trim	Trim unnecessary connections at the beginning and end of the winding
By Layer	Color the coils by choosing by layer option or by Match properties
Mirror	Select object: All end conductors Base: mid point of all conductors
Line Trim	Join all the three coil group sets with two connectors for the bottom connection side.
Line Trim Circle	Use " End to End" and "Start to Start" pattern and connect all the coil groups
Line Copy	Mark the arrow heads for defining poles
Text	Mark R1, R2, Y1, Y2, B1,B2

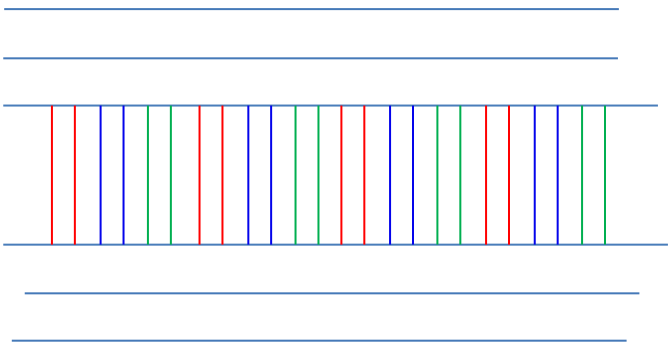
3. 24 slots, 4 pole, un – Bifurcated winding in 2 tier

Steps for drawing the winding diagram:

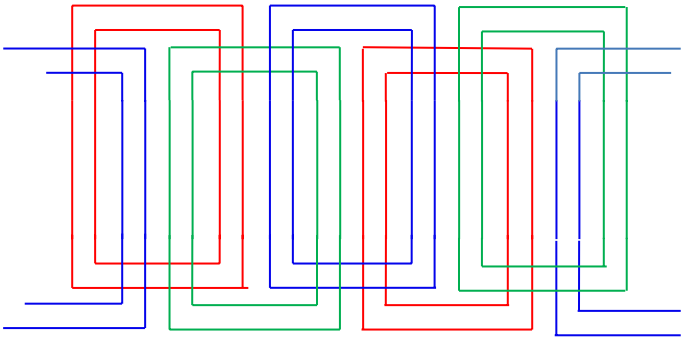
Step 1: Draw the conductors using line command, offset it, and colour using the "By layer" option or from match properties as shown below:



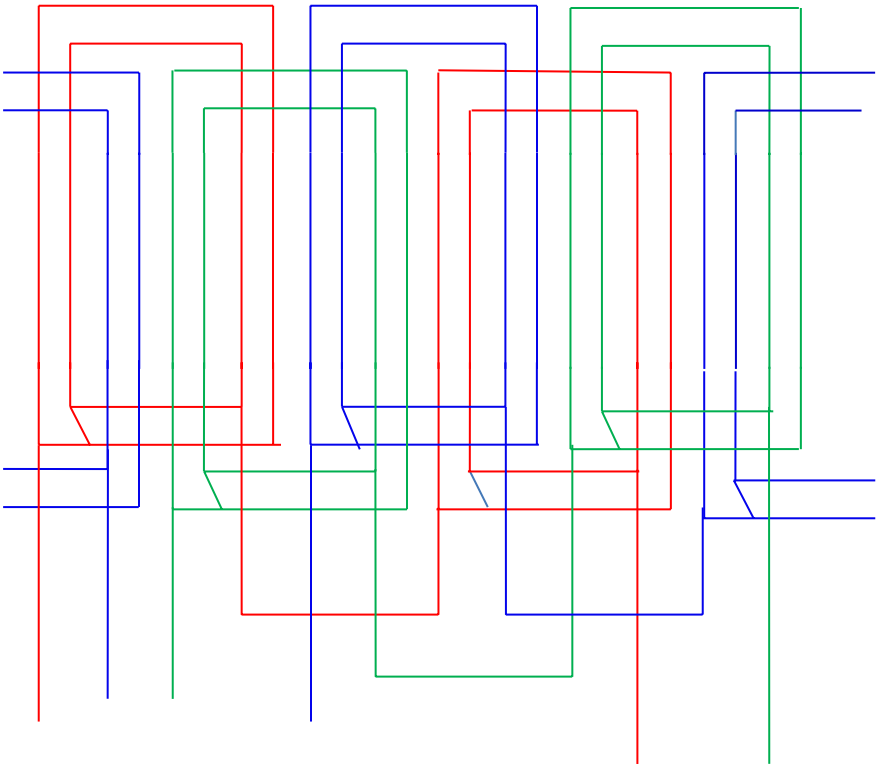
Step 2: Draw the 2 tier using line command with suitable dimensions:



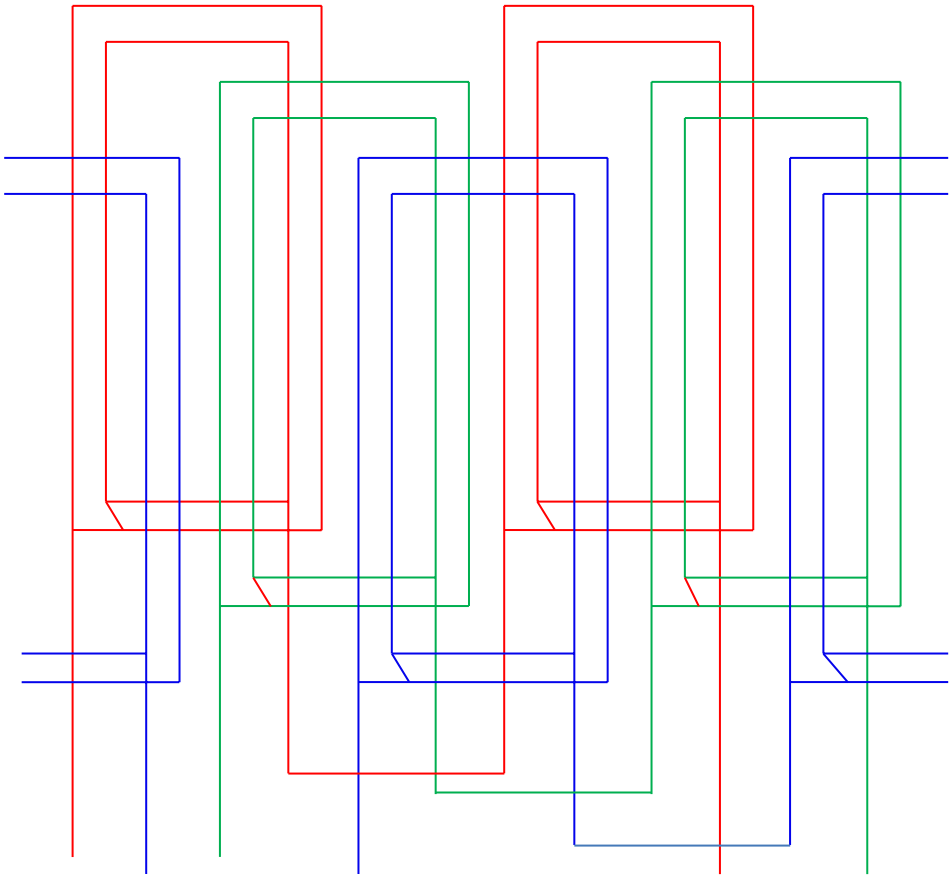
Step 3: Join the conductors to form coil groups as shown below:



Step4: Use " End to End" and "Start to Start" pattern and connect all the coil groups and mark the text as required.

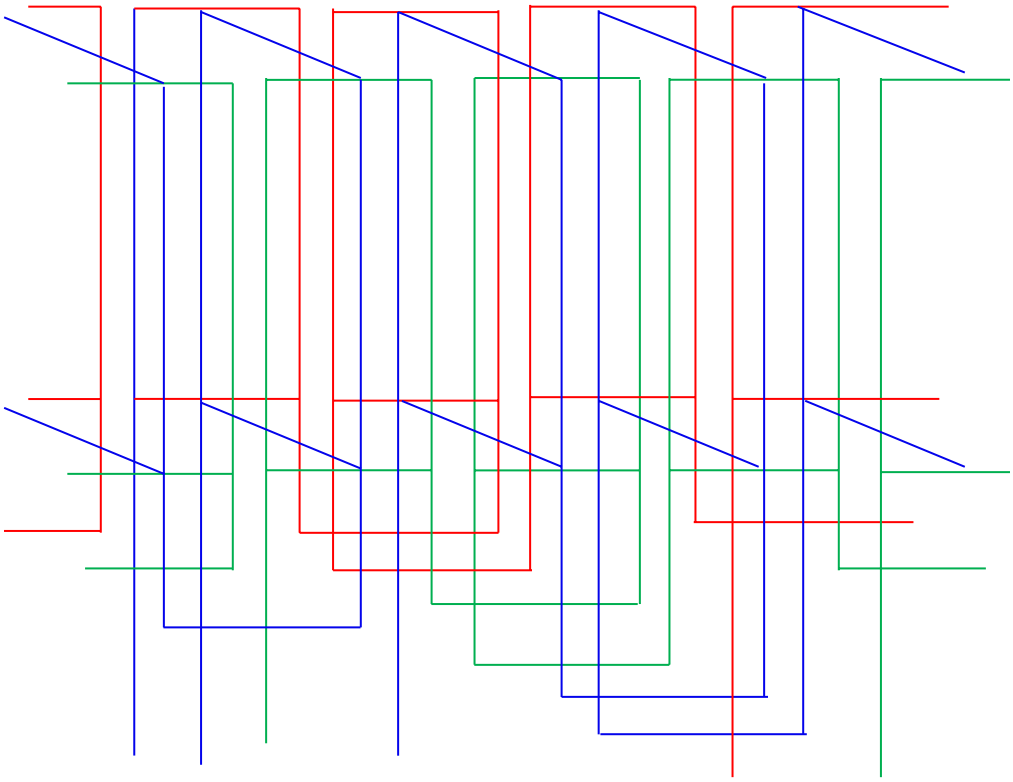


4. 24 slots, 4 pole, un – Bifurcated winding in 3 tier

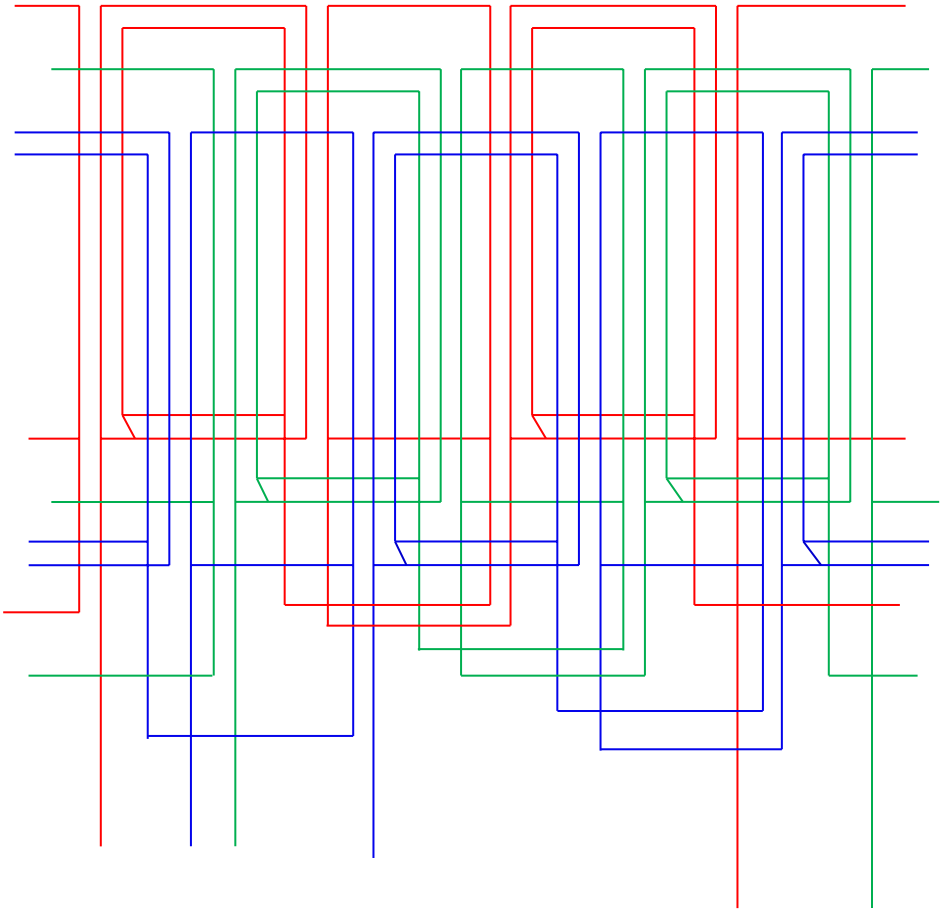


Note: Follow the similar steps explained above and form the winding diagram.

5. 24slots, 4 pole, Bifurcated winding in 2 tier



6.**36 slots, 4 pole, Bifurcated winding in 3 tier**



7. Mush Winding Diagram

Draw the developed AC Mush Winding Diagram for the following diagram:

No. of. Slots= 24

No. of. Poles=4

Type: Single layer

Coil Pitch=Full Pitch, i.e Pole Pitch

Overhang type: Mush type(6/6)

Type of winding: Lap

Solution:

No. of. Slots=24

No. of. Poles=4

Yp= Pole pitch

Yc= Coil pitch

Slot angle= 180/(S/P)= 30 degree

No. of. Slots/Pole/Phase, m=2

Yp=Pole Pitch=S/P= 6

Pitch=6/6

1+6=7

Steps for drawing the winding diagram:

Command	**Details**
Units	Mm
Limits	(0,0) (1000,1000)
Zoom, All	
Line	First Point: 20,130 Next Point: @40<270 Press Enter
Array	Rows: 1 Column: 24 Row offset: 0 Column offset: 10 Select object: Select conductor
Text	Specify first & opp corner whereever text required Type the text Press OK Array the text written.
By Layer	Select colours for the conductors
Line	Form the overhang First point: End point of conductor 2 Second point: @20<90 First point: End point of conductor 7 Second point: @10<90 Join the points
Array	Rectangular Columns: 12 Row: 1 Column Offset:20 Select object: Select complete overhang
Array	Rectangular Columns: 4 Row: 1

	Column Offset:-20 Select object: Select complete overhang
Mirror	Select object: Select upper over hang Base: mid point of all conductors
Line	Draw current directions
Line Trim Circle	Use " End to End" and "Start to Start" pattern and connect all the coil groups
Text	Mark R1, R2, Y1, Y2, B1,B2

Outcome :

- Students will be able to draw the Integral and Fractional slot double layer Lap and Wave winding diagram for ac machines
- Students will be able to Students will be able to draw the Integral and Fractional slot double layer Lap and Wave winding diagram for ac machines