Electrical Drawing
AC 3ϕ Double Layer Short Pitch

1. Draw AC winding with <u>double layer</u>, with 24 slots and 2 poles, and short pitched by one slot

1. Calculations
Slots = 24
Poles = 2
Number of slots shorted = 1
Slot pitch = 24/2 = 12
Slot angle = 180^o/slot pitch = $180^o/12 = 15^o$
Slot/pole/phase = 24/2/3 = 4 - under each pole, there are 4 Red, 4 Blue, 4 Yellow slots
Coil span = slot pitch – slots shorted = 12-1=11

Assume RYB connection
Red starts from 1st conductor, by default
Yellow starts from 1+120/15 = 9
Blue starts from 1+240/15 = 17

2. Notes
a. In double layer, each slot contains two conductors. Numbering is done for the slot, not individual conductors
b. Top conductor must be connected to the Bottom conductor
c. Top conductor, drawn as solid line, tilts right
d. Bottom conductor, drawn as dotted line, tilts left
e. Double layer AC winding coils are hexagonal in shape

3. Slot position table
Slot/pole/phase = 24/2/3 = 4

Slots	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Top	R	R	R	R	B	B	B	B	Y	Y	Y	Y	R	R	R	R	B	B	B	B	Y	Y	Y	Y
Bottom	R^1	R^1	R^1	R^1	B^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	Y^1	R^1	R^1	R^1	R^1	B^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	Y^1

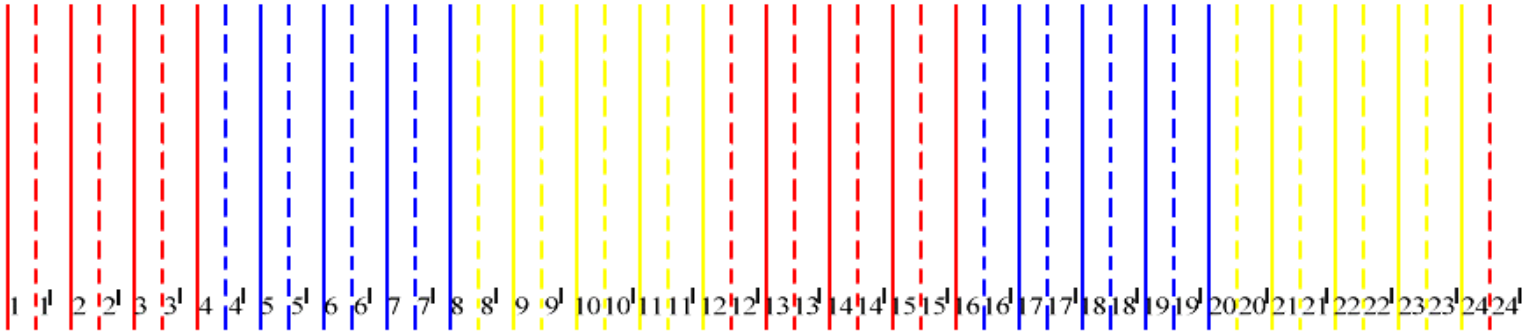
Coil span is 11. 1st conductor must be connected to 1+11=12th conductor.
1st top conductor must be connected to 12th bottom conductor. But 1st top is Red, while 12th bottom is Yellow. Conductor of one phase (Red) cannot be connected to conductor of another phase (Yellow). These kinds of problems arise only in short pitch windings. To solve this, the bottom set of conductors is <u>shifted by one slot towards left</u>. The corrected slot position table is as below:

Slots	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Top	R	R	R	R	B	B	B	B	Y	Y	Y	Y	R	R	R	R	B	B	B	B	Y	Y	Y	Y
Bottom	R^1	R^1	R^1	B^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	Y^1	R^1	R^1	R^1	R^1	B^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	Y^1	R^1

The bottom red that was shifted left will be accommodated in the 24th slot
1st top Red conductor can now be connected to 12th bottom conductor which is also red. So this is the correct position of the conductors.
Note: If number of slots shorted is 2, the bottom set must be <u>shifted by two slots towards left</u>

3. Winding diagram

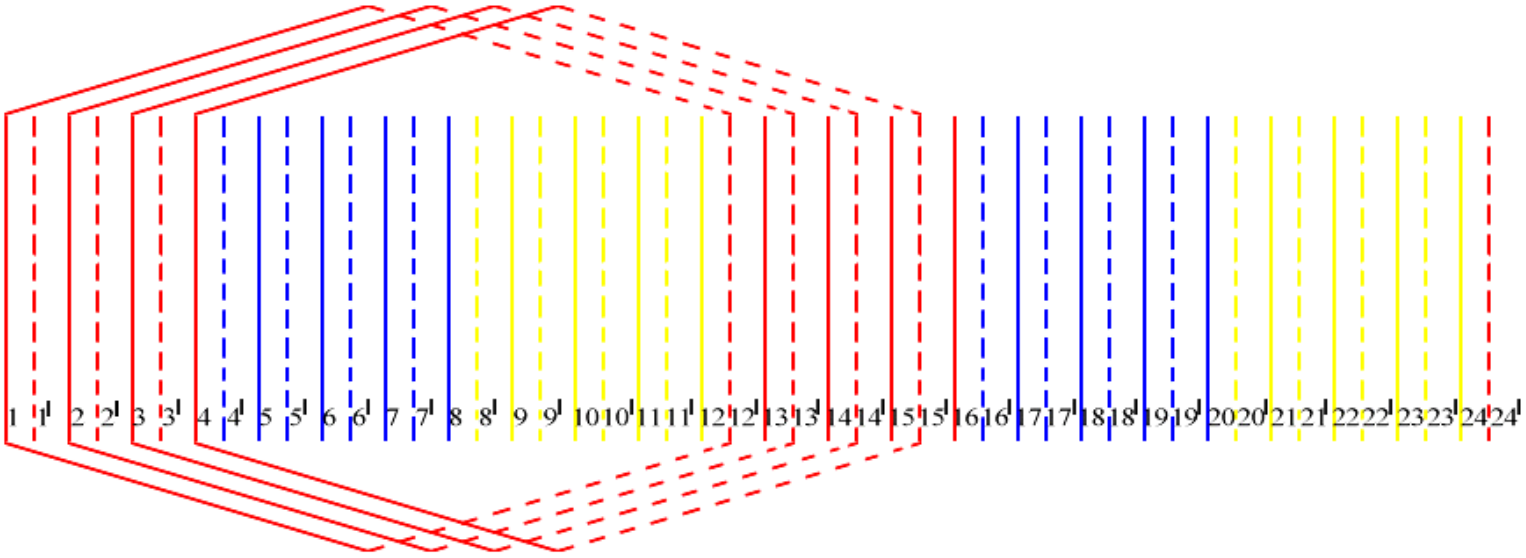
3.1 Draw the conductors according to the slot position table and number them



Note: In short pitched double layer windings, a slot may contain conductors belonging to different phases. For example, slot number 4 contains Red at the top and Blue as the bottom conductor. Slot number 12 has Yellow as the top conductor, Red as the bottom conductor

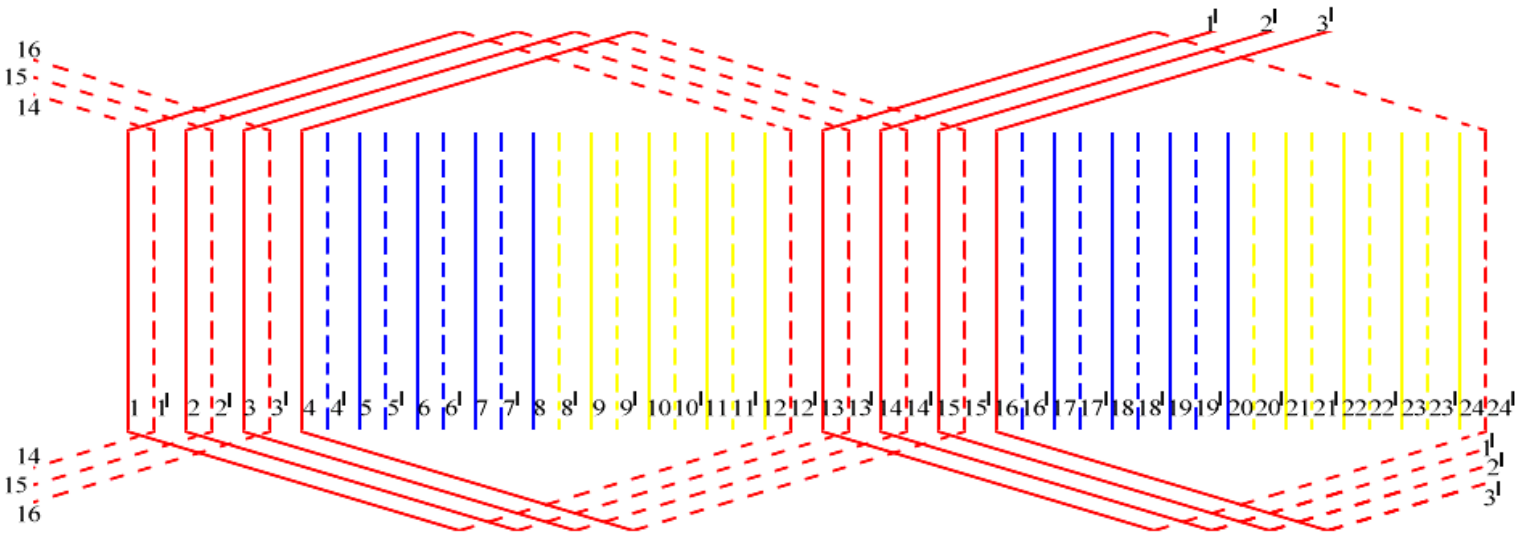
3.2 Draw the overhanging conductors, phase by phase.

Start by Red. 1+11 = 12. 1st slot top red must be connected to 12th slot bottom red. Note that the 12th slot top conductor is Yellow, not Red



3.3 Similarly, make the other connections for Red

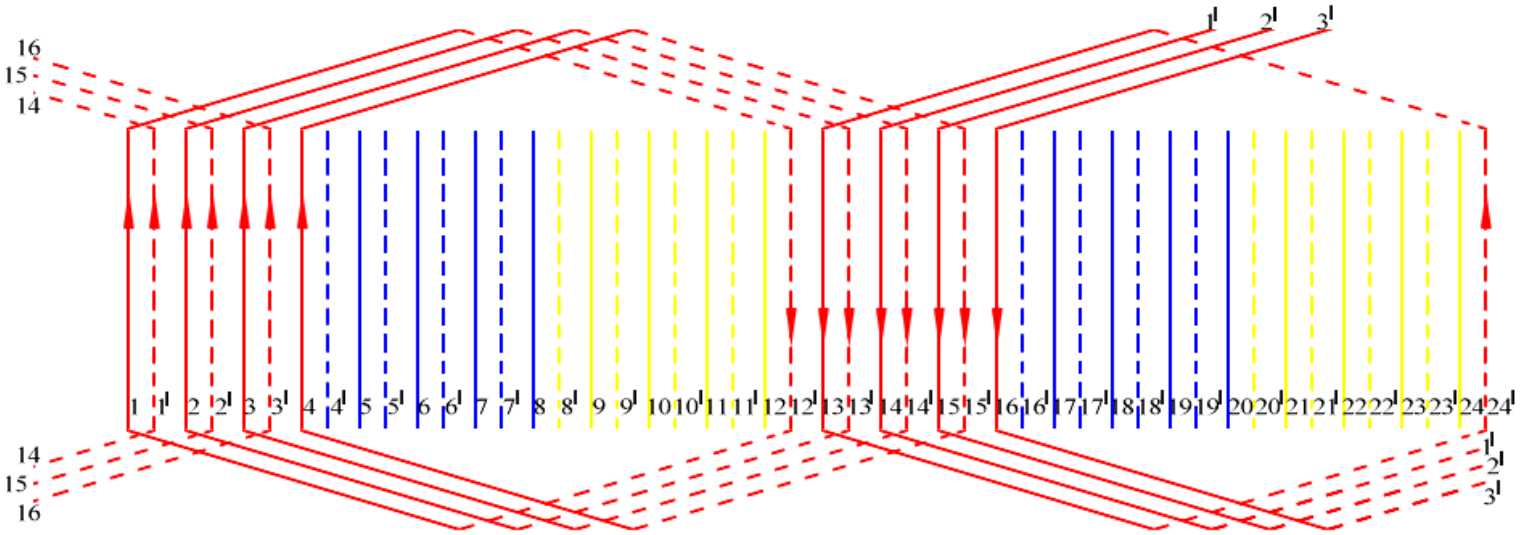
Top +11	**Bottom**
13	24
14	25 (1)
15	26 (2)
16	27 (3)



3.4 Draw current directions for all conductors

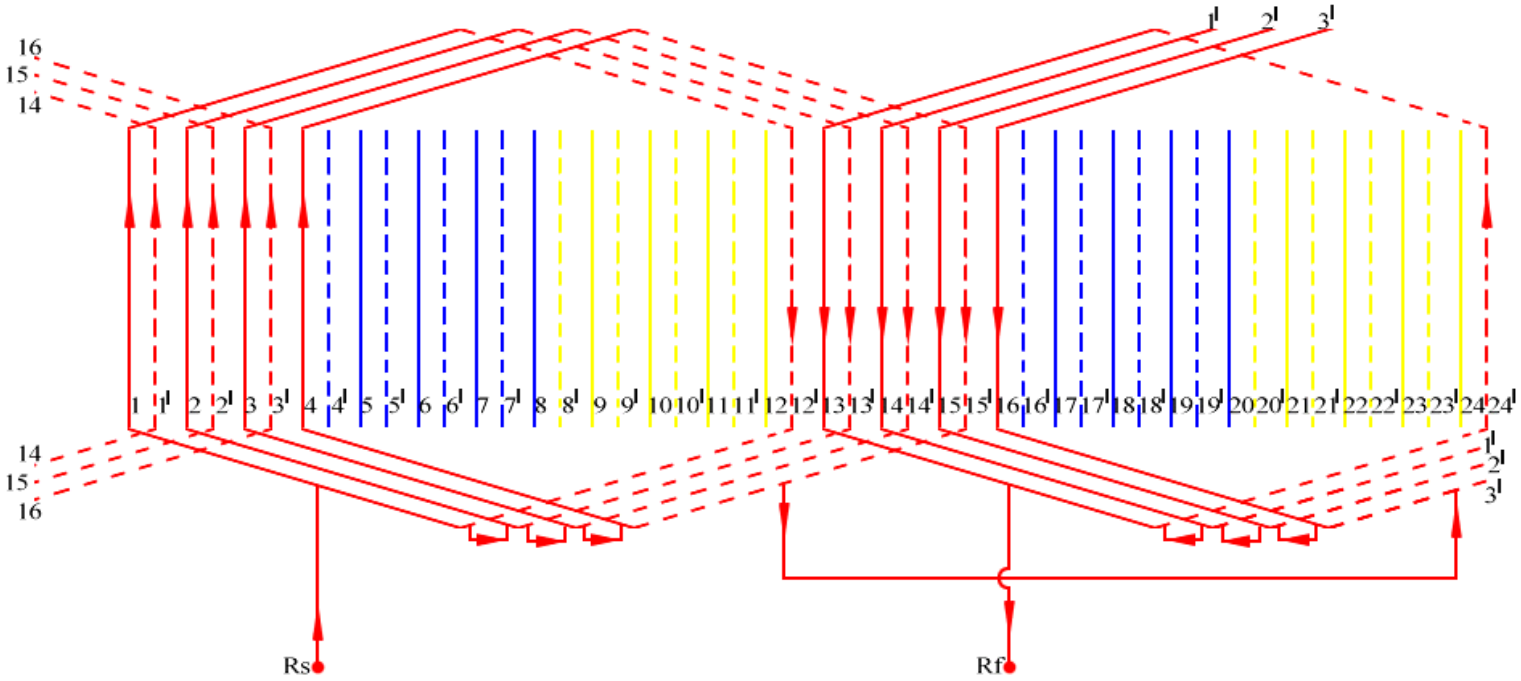
By default, for AC windings, current flows in upward direction under North pole, and downward direction under South pole.

Slot pitch is 12. In first 12 slots, current flows in upward direction, next 12m in downward direction. But since this is short pitched by one slot, the first bottom (dotted) conductor is shifted to the 24th slot. So the current direction for Red conductors is as below.



Note: In any loop, current flows in one single direction. That is, if current flows <u>up</u> in 1, it flows <u>down</u> in the second conductor of same turn (loop) 12^1. Similarly, if current flows down in 15, it means that in the other conductor of same loop, 2^1, it flows up. Same is the case for Yellow and Blue phases also.

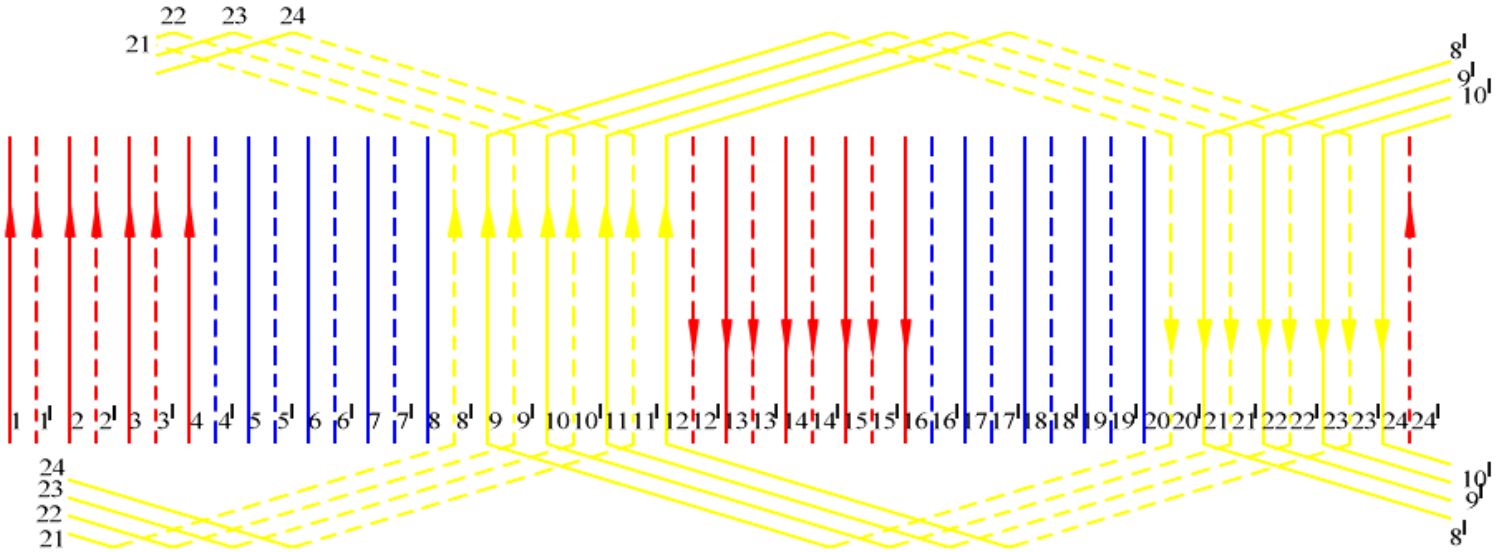
3.5 Draw connections connecting all red loops to complete the Red phase



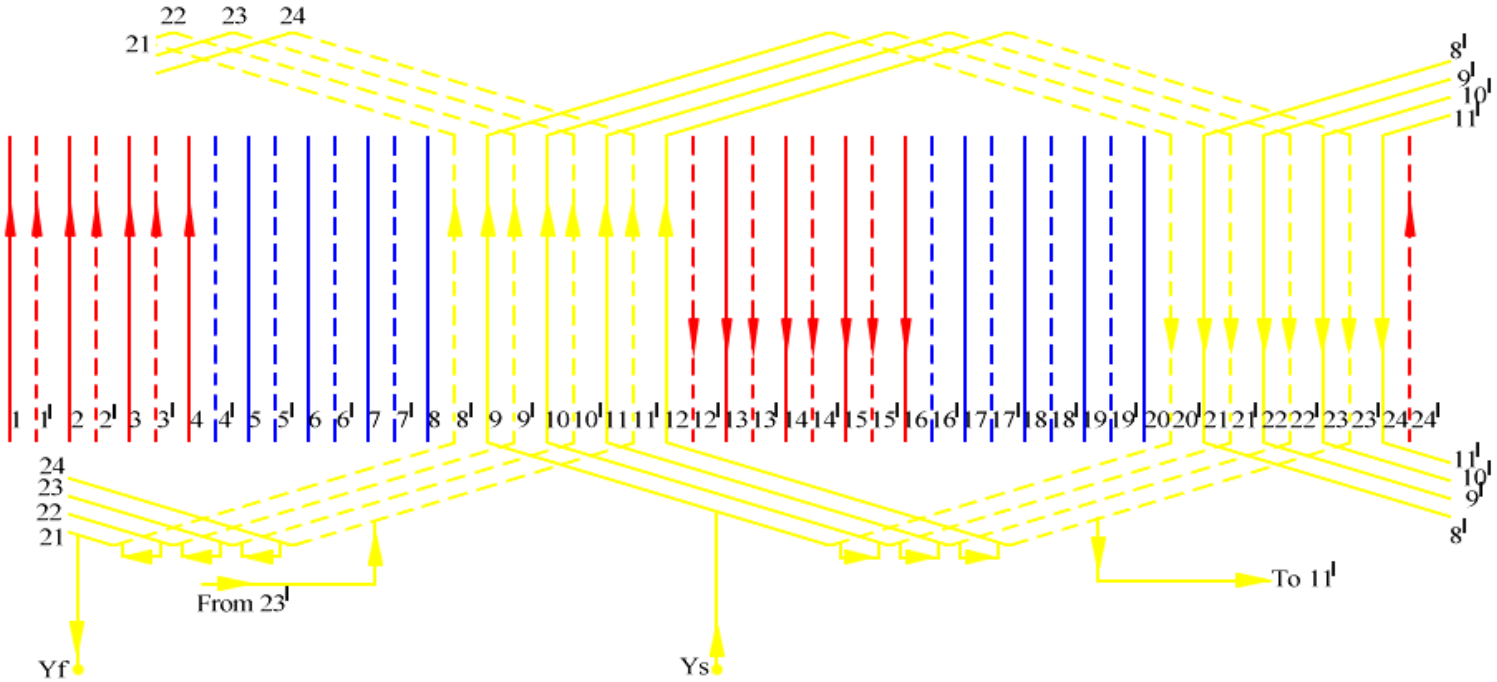
a. Flow starts from R_S, goes up 1, then down 12^1, loops right, and goes up 2
b. It goes up 2, comes down 13^1, loops right, and goes up 3
c. 3 up, 14^1 down, loop right, 4 up
d. 4 up, 15^1 down, and out of 15^1
e. Since it is coming **down** out of 15^1, in the next set of loops, flow must go **up**. So connection must be connected to 3^1 in which current is flowing up
f. The flow goes up 3^1 and down 16, loops left, and goes up 2^1
g. 2^1 up, 15 down, loop left, 1^1 up
h. 1^1 up, 14 down, loop left, 24^1 up
i. 24^1 up, 13 down, and comes down out of 13. This is end of Red phase, R_F.

Note: Numbers with superscripts (1^1, 2^1, …24^1) are conductors at the bottom of the slot, drawn using dotted lines

3.6 Connections for Yellow is similar to Red
Yellow starts from 9th conductor

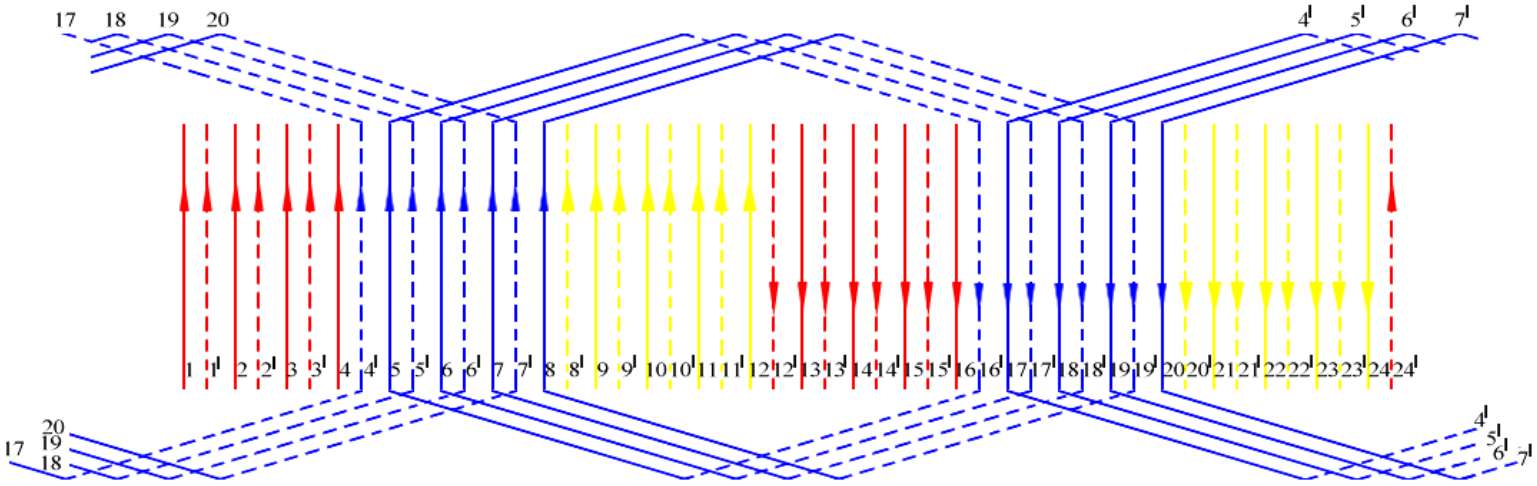


3.7 Draw connections connecting all yellow loops to complete the Yellow phase

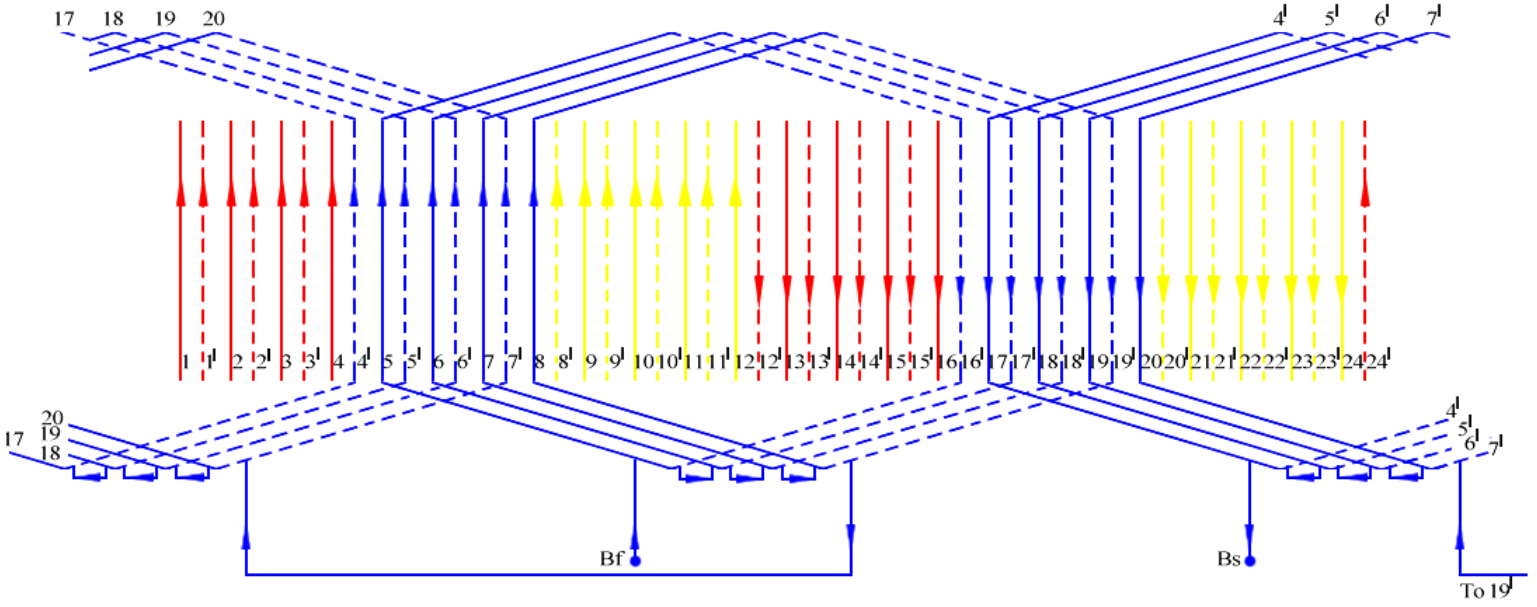


a. Flow in Yellow phase starts in 9th conductor (Y_S). After going through all other loops, it comes down out of 23^1
b. From 23^1, the flow goes up and joins 11^1 where the current is going up.
c. After going through the loops of the second set, the phase ends by coming out of 21 (Y_F)

3.8 Blue phase starts from 17th conductor
Draw all Blue overhanging conductors, number them, and place the arrows as done for Red and Yellow

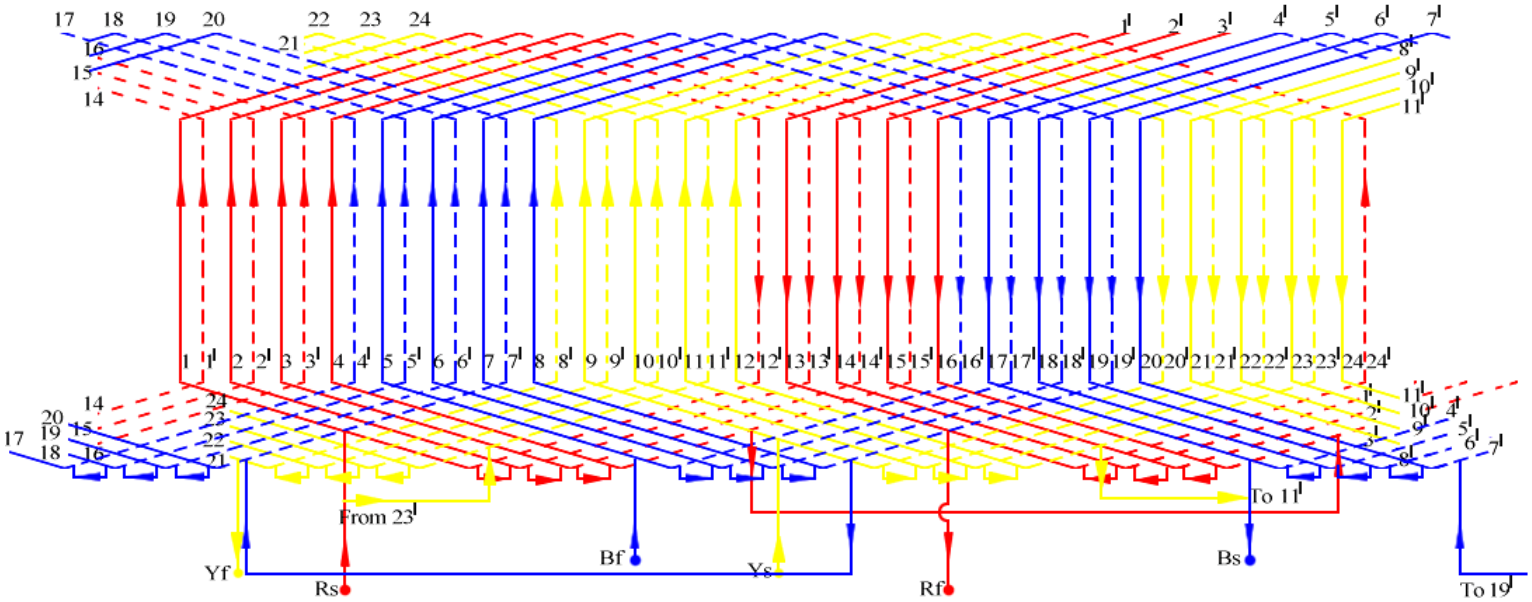


3.9 Complete the connections between the loops



a. For Blue, direction of arrows (current direction) is opposite to other phases. That is, current flows <u>out</u> of B_S, and <u>into</u> B_F
b. Current flows down 17, down 4^1, loops through other loops in that set of Blues and comes out of 7^1
c. 7^1 up, 19^1 down, loops through other loops and comes out of 5, which is the last conductor in Blue phase, B_F.

3.10 The completed winding diagram for all RYB phases



2. Draw double layer AC winding with 36 slots, 4 poles, short pitched by 1 slot

a. Calculations:
slot pitch = 36/4 = 9
slot angle = 180/9 = 20^{o} electrical
slot/pole/phase = 36/4/3 = 3
coil span = slot pitch-1 = 9-1 = 8

R – 1
Y – 1+120/20 = 7
B – 1+240/20 = 13

Since it is short pitched by 1 slot, bottom set of conductors must be shifted left by 1 slot. So bottom of first Red will be bottom of 24^{th} slot

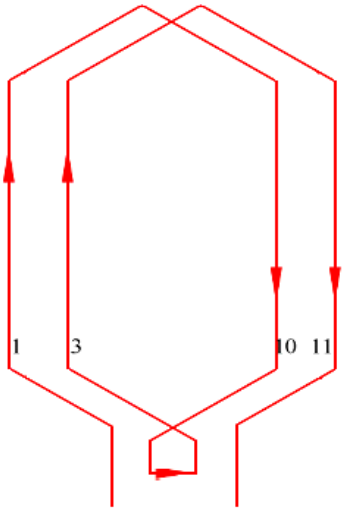
b. Slot position table:

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Top	R	R	R	B	B	B	Y	Y	Y	R	R	R	B	B	B	Y	Y	Y
Bottom	R^1	R^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	R^1	R^1	R^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	R^1

	19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Top	R	R	R	B	B	B	Y	Y	Y	R	R	R	B	B	B	Y	Y	Y
Bottom	R^1	R^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	R^1	R^1	R^1	B^1	B^1	B^1	Y^1	Y^1	Y^1	R^1

Note: In the 3^{rd} slot, top solid line is Red, the bottom dotted line is Blue
Top of 1^{st} slot must connect to $1+8=9^{th}$ slot bottom Red conductor

Note: The actual connection in a practical machine is as below



In practical machines, conductors 10 and 1, or 3 and 11 are <u>not</u> shorted. The connection in fact, is as given in the diagram. But while drawing the winding diagram, loops are drawn as if two sides of a winding are connected to each other, i.e., shorted, forming a circular (hexagonal) loop.