Q1)

In this part, 72 slot, 6-pole, 3 phase machine with double layer winding configuration is investigated. For this machine, slots per pole per phase is found as,

The electrical angle between coils is found by following formula.

1. Firstly, winding diagram of the full pith winding is obtained and shown in Figure.



Winding diagram of the other option which is 11/12 short-pitched winding is shown in Figure.



b) The distribution factor shows how the distribution of coils affect the total induced emf. The electrical angle between windings results in different phases for different winding of the same coil. Hence the resulting voltage is obtained by vectoral summation. Distribution factor is the ratio of vectoral sum over algebraic sum.

For this machine distribution factor is found as,

The pitch factor is the representation of the coil span. If the return path of the coil is not at the opposite of the positive path, resultant back emf becomes smaller. Pitch factor is found by following formula where is the coil span in electrical angels.

For full pitch winding diagram, pitch factor is unity.

For 11/12 short-pitched winding, pitch factor is found as,

Winding factor is the multiplication of distribution and the pitch factor. For full pitch winding,

Winding factor of 11/12 short-pitched winding is calculated as,

c)

Distribution and pitch factor of 3rd and 5th harmonics are given below for full and 11/12 short-pitched winding designs.

The resulting winding factors are calculated accordingly.

d) Distribution factor reduces the voltage of the fundamental harmonic just by 4.3%. However, it significantly helps to reduce the 3rd and 5th harmonic voltages, which are not desired. For short pitch configuration, fundamental harmonic voltage decreases about 1% which is not negligibly small, whereas, 3rd and 5th harmonic voltages decrease about 8% and 20% respectively.   
In short, adjusting the distribution and span of coils, unwanted harmonics can be eliminated considerably.

Q2)

A three-phase permanent magnet synchronous machine which has 20 poles is investigated in this part. Firstly, slot number is chosen as 24. For this configuration, phase angles of induced voltage in each slot are given in Table below.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1st | 0° | 7th | 180° | 13th | 0° | 19th | 180° |
| 2nd | 150° | 8th | 330° | 14th | 150° | 20th | 330° |
| 3rd | 300° | 9th | 120° | 15th | 300° | 21st | 120° |
| 4th | 90° | 10th | 270° | 16th | 90° | 22nd | 270° |
| 5th | 240° | 11th | 60° | 17th | 240° | 23rd | 60° |
| 6th | 30° | 12th | 210° | 18th | 30° | 24th | 210° |

The phasor diagram of Phase-A is given in below Figure.



The distribution factor is found by vectoral sum over algebraic sum. Due to symmetry, sum of two vectors with angle between 30° can be used.

The coil span is 180° as shown in the Figure. Hence pitch factor is unity. Thus, winding factor is equal to distribution factor.

Now the same machine is analyzed for 21 slots. The phase angles of induced voltage in each slot are given in Table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1st | 0° | 8th | 120° | 15th | 240° |
| 2nd | 171.43° | 9th | 291.43° | 16th | 51.43° |
| 3rd | 342.86° | 10th | 102.86° | 17th | 222.86° |
| 4th | 154.28° | 11th | 274.28° | 18th | 34.28° |
| 5th | 325.71° | 12th | 85.71° | 19th | 205.71° |
| 6th | 137.14° | 13th | 257.14° | 20th | 17.14° |
| 7th | 308.57° | 14th | 68.57° | 21st | 188.57° |