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Furkan Tokgöz

**EE568**

**Project-2**

**1)**

**Motor Parameters:**

* Q=120 (Number of slot)
* p=20 (Number of poles)
* m=3 (Number of phases)
* q=120/20.3=2 (Number of slot/pole/phase)
* θ=180.20/120=30 (Phase difference betw0een each slot)
* Double-layer
* Full-pitch winding

**Winding Diagram:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ***Slot number*** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** | ***11*** | ***12*** |
| First Layer | A | A | -C | -C | B | B | -A | -A | C | C | -B | -B |
| Second Layer | A | A | -C | -C | B | B | -A | -A | C | C | -B | -B |

**Distribution Factor:**

i)Fundamental

ii) The Third Harmonic

iii) The Fifth Harmonic

**Pitch Factor:**

i) Fundamental

i) The Third Harmonic

Note that, negative sign implies that third harmonic rotates in negative direction compared to fundamental.

i) The Fifth Harmonic

**Winding Factor:**

i) Fundamental

i) The Third Harmonic

i) The Fifth Harmonic

The winding factor of the fundamental is very close to unity. The higher the winding factor, the greater the induced voltage. So, it is desired to have a high winding factor for fundamental and low winding factors -even equal to zero- for the harmonics if a pure sinusoidal induced voltage is aimed. If the design was short-pitched rather than full-pitched, one could achieve zero winding factor for specific harmonic orders. One interesting detail to note here might be that the third harmonic is rotating in reverse direction. This might cause a high induced voltage in high speeds, since the relative frequency difference between rotor and MMF of the third harmonic will increase immensely.

**2)**

**A)**

**Motor Parameters:**

* Q=21
* p=20
* m=3
* q=21/20.3=7/20
* θ=180.20/21=1200/7=171.43

**Winding Diagram:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Slot Number** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** | ***11*** | ***12*** | ***13*** | ***14*** | ***15*** | ***16*** | ***17*** | ***18*** | ***19*** | ***20*** | ***21*** |
| **First Layer** | A | -A | A | -A | A | B | -B | B | -B | B | -B | B | C | -C | C | -C | C | -C | C | A | -A |
| **Second Layer** | A | -A | A | -A | -B | B | -B | B | -B | B | -B | -C | C | -C | C | -C | C | -C | -A | A | -A |
| **Phase of Fundamental Voltage** | **0** | 171 | 343 | 154 | 326 | 137 | 309 | **120** | 291 | 103 | 274 | 86 | 257 | 69 | **240** | 51 | 223 | 34 | 206 | 17 | 189 |
| **Phase of Third Harmonic** | 0 | 154 | 309 | 103 | 257 | 51 | 206 | 0 | 154 | 309 | 103 | 257 | 51 | 206 | 0 | 154 | 309 | 103 | 257 | 51 | 206 |
| **Phase of Fifth Harmonic** | 0 | 137 | 274 | 51 | 189 | 326 | 103 | 240 | 17 | 154 | 291 | 69 | 206 | 343 | 120 | 257 | 34 | 171 | 309 | 86 | 223 |

Phase angles of the induced voltages are calculated in Excel as follows:

As can be seen in Table.2, induced voltages of each phases are 120 degree apart from each other. A rotating MMF waveform is achieved by fractional slot winding. Phasor diagram of the designed motor can be seen in Fig.1.

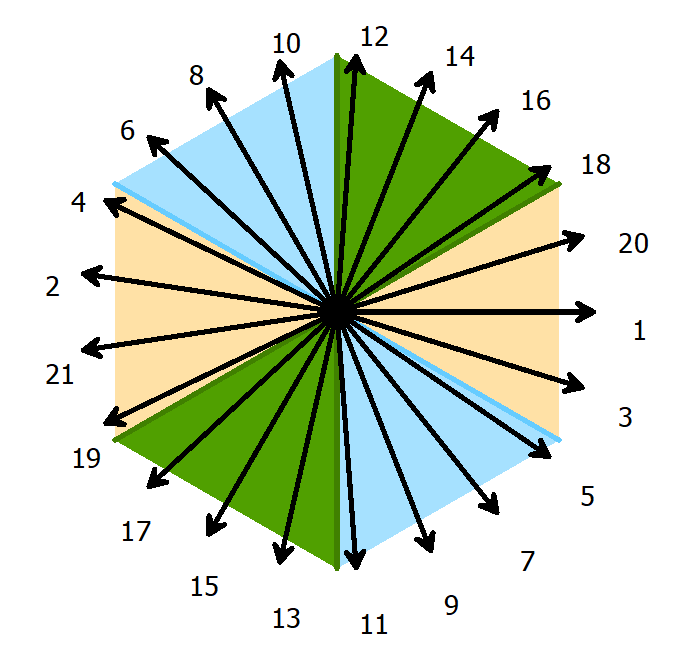


Figure 1. Phasor diagram of the designed motor.

**Distribution Factor:**

Since, it is a fractional slot winding, slot per pole per phase value becomes smaller than one which makes distribution factor greater than unity. So, distribution factor is calculated from the ratio of vector sum to the scalar sum of the voltages.

i) Fundamental

ii) The Third Harmonic

Fractional slot with third harmonic resulted in unbalanced MMF creation. As can be seen in formula, there were 9 vectors in one region. The other two regions had 6 vectors. As a result, a rotating balanced MMF cannot be created with this configuration.

iii) The Fifth Harmonic

**Pitch Factor:**

i) Fundamental

i) The Third Harmonic

i) The Fifth Harmonic

**Winding Factor:**

i) Fundamental

i) The Third Harmonic

i) The Fifth Harmonic

**B)**

**Motor Parameters:**

* Q=27
* p=20
* m=3
* q=27/20.3=7/20
* θ=180.20/27=1200/7=171.43

**Winding Diagram:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Slot Number** | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** | ***6*** | ***7*** | ***8*** | ***9*** | ***10*** | ***11*** | ***12*** | ***13*** | ***14*** | ***15*** | ***16*** | ***17*** | ***18*** | ***19*** | ***20*** | ***21*** | ***22*** | ***23*** | ***24*** |
| **First Layer** | A | -A | -B | B | C | -C | -A | A | B | -B | -C | C | A | -A | -B | B | C | -C | -A | A | B | -B | -C | C |
| **Second Layer** | A | -B | -B | -C | C | A | -A | -B | B | C | -C | -A | A | B | -B | -C | C | A | -A | -B | B | C | -C | -A |
| **Phase of Fundamental Voltage** | **0** | 133 | 267 | 40 | 173 | 307 | 80 | 213 | 347 | **120** | 253 | 27 | 160 | 293 | 67 | 200 | 333 | 107 | **240** | 13 | 147 | 280 | 53 | 187 |
| **Phase of Third Harmonic** | 0 | 40 | 80 | 120 | 160 | 200 | 240 | 280 | 320 | 0 | 40 | 80 | 120 | 160 | 200 | 240 | 280 | 320 | 0 | 40 | 80 | 120 | 160 | 200 |
| **Phase of Fifth Harmonic** | 0 | 307 | 253 | 200 | 147 | 93 | 40 | 347 | 293 | 240 | 187 | 133 | 80 | 27 | 333 | 280 | 227 | 173 | 120 | 67 | 13 | 320 | 267 | 213 |

Phase angles of the induced voltages are calculated in Excel as follows:

As can be seen in Table.2, induced voltages of each phases are 120 degree apart from each other. A rotating MMF waveform is achieved by fractional slot winding. Phasor diagram of the designed motor can be seen in Fig.2.

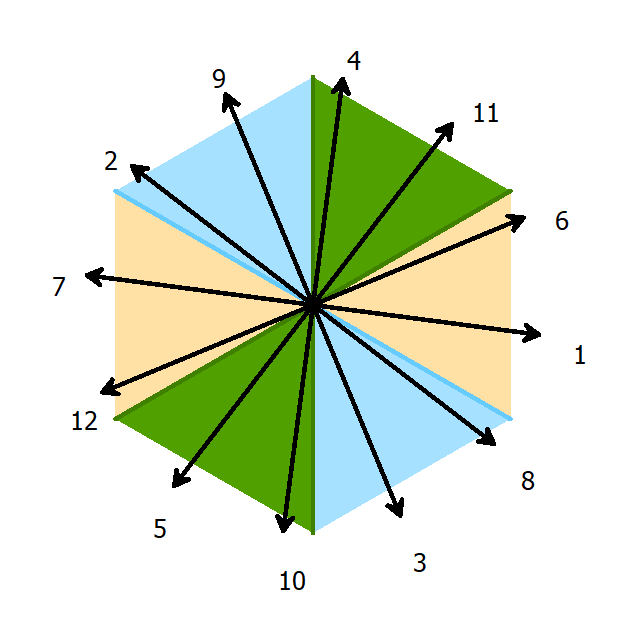


Figure 2. Phasor diagram of the designed motor

**Distribution Factor:**

Since, it is a fractional slot winding, slot per pole per phase value becomes smaller than one which makes distribution factor greater than unity. So, distribution factor is calculated from the ratio of vector sum to the scalar sum of the voltages.

i) Fundamental

ii) The Third Harmonic

Fractional slot with third harmonic resulted in unbalanced MMF creation. As can be seen in formula, there were 9 vectors in one region. The other two regions had 6 vectors. As a result, a rotating balanced MMF cannot be created with this configuration.

iii) The Fifth Harmonic

**Pitch Factor:**

i) Fundamental

i) The Third Harmonic

i) The Fifth Harmonic

**Winding Factor:**

i) Fundamental

i) The Third Harmonic

i) The Fifth Harmonic