EE4001 AC Machines

ED Chapter 9: AC Machines Space Vectors

Problem 1: ED 9-3

Problem 2: ED 9-6
[Ans. $15\angle 0°$ A; $15\angle 120°$ A; $15\angle 240°$ A;]

Problem 3: ED 9-7
[Ans. 86.6 V, -86.6 V, 0 V]

Problem 4: ED 9-8

Problem 5: ED 9-9
[Ans. $0.628\angle 0°$ T ; 3600 rpm]

Problem 6: ED 9-10
[Ans. 1200 rpm]

Problem 7: ED 9-12
[Ans. $255\angle 0°$ V, $10.6\angle -90°$ A]

Summer 2004
Problem 8: ED 9-13
Derive an expression for the self inductance for a single phase of a three-phase machine with sinusoidally-distributed windings. Ignore machine parasitics, and assume energy storage in the airgap only.

Problem 9: ED 9-14

Problem 10:
A 2-pole, 3-phase induction motor has the following physical dimensions: radius r = 7 cm, length l = 9 cm, airgap length l_g = 0.5 mm, and number of turns per phase per pole N_{sp} = 30. The star-connected motor is supplied by a rated voltage of 208 V (line to line) at a frequency of 60 Hz.

(i) Develop an expression for the per-phase magnetizing inductance.
(ii) Calculate the per-phase magnetizing inductance and the per-phase magnetizing current of the machine.
(iii) Determine the peak magnitudes of the following rotating space vectors: stator current, voltage and flux density.

[Ans. (i) 67.2 mH, 4.74 A (ii) 10.1 A, 254.8 V, 0.76 T]

Problem 11:
A 2-pole, 3-phase induction motor has the following physical dimensions: radius r = 6 cm, length l = 24 cm, airgap length l_g = 1.5 mm, and number of turns per phase per pole N_{sp} = 50. The star-connected motor is supplied by a rated voltage of 208 V (line to line) at a frequency of 60 Hz.

(i) Calculate the per-phase magnetizing inductance and the per-phase magnetizing current of the machine.
(ii) Determine the peak magnitudes of the following rotating space vectors: stator current, voltage and flux density.
(iii) Determine the rms per-phase current and output torque when a per-phase reflected current I'_r = 10 A flows in the stator.
(iv) Roughly sketch a space vector diagram showing the approximate phase angles and magnitudes of the space vector voltage, the magnetizing space vector current, the reflected rotor current, and the stator current.

[Ans. (i) 0.142 H, 2.24 A (ii) 4.76 A, 254.8 V, 0.2 T (iii) 10.25 A, 4.53 Nm]

Summer 2005, Summer 2004
Problem 12:
A 4-pole, 3-phase induction motor has the following physical dimensions: radius r = 6 cm, length l = 24 cm, airgap length l_g = 0.5 mm, and number of turns per phase per pole N_{sp} = 50. The star-connected motor is supplied by a rated voltage of 400 V (line to line) at a frequency of 50 Hz.

(i) Calculate the per-phase magnetizing inductance and the per-phase magnetizing current of the machine.
(ii) Determine the magnitudes of the following rotating stator space vectors: current, voltage and flux density.
(iii) Determine the rms per-phase current and output torque when a per-phase reflected current I'_r = 5 A flows in the stator.

[Ans. (i) 0.426 H, 1.72 A (ii) 3.66 A, 490 V,0.46 T(iii) 5.29 A, 14.7 Nm]

Summer 2006
Problem 13:

A 2-pole, 3-phase induction **generator** has the following physical dimensions: radius r = 6 cm, length l = 24 cm, airgap length l_g = 1 mm, and number of turns per phase per pole N_{sp} = 50. The star-connected generator is connected to a rated voltage of 400 V (line to line) at a frequency of 50 Hz.

(i) Calculate the per-phase rms magnetizing current of the machine.
(ii) Determine the peak of the space vector flux density.
(iii) Determine the input torque when a rms per-phase reflected current I'_r = 5 A flows in the stator.
(iv) Sketch a space vector diagram showing the approximate phase angles and magnitudes of the space vector voltage, the magnetizing current, the reflected rotor current, and the stator current.

[Ans. 3.45 A, 0.46 T, 7.67 Nm]

Problem 15: ED Ex 11-1

ED Chapter 13

Problem 1
In a 2-pole induction machine, a peak per-phase magnetizing current of 4 A is required to establish the rated airgap flux density. A step change from 0 to rated torque requires a step change in the stator quadrature-axis current i_{sq} = 10 A. A slip speed f_{slip} = 1.8 Hz is required for steady state operation at rated torque.

(i) Calculate the magnitudes of the space-vector current $I_{ms,pk}$, the stator direct-axis current i_{sd}, and the three phase currents, i_a, i_b, and i_c, to establish the rated flux at $t = 0^-$.
(ii) Calculate $I_{ms,pk}$ and the three phase currents to establish the rated torque at $t = 0^+$.
(iii) Assuming that the rotor is blocked, calculate the electrical input frequency and the phase currents at t = 8 ms.
(iv) Assuming that the rotor speed is constant at 1100 rpm, calculate the electrical input frequency and phase currents at t = 8 ms.

[Ans. (i) 6 A, 4.9 A, 4 A, -2 A, -2 A (ii) 13.64 A, 4 A, 5.07 A, -9.07 A (iii) 1.8 Hz, 3.25 A, 5.73 A, -8.98 (iv) 20.13 Hz, -4.80 A, 9.09 A, -4.28 A.]

Summer 2005
Problem 2
In a 4-pole induction machine, a per-phase current of 106 Arms at an input electrical frequency of 50 Hz is required to establish the rated airgap flux density. A per-phase current of 225 Arms at an input electrical frequency of 51.5 Hz is required to establish rated motoring torque at a mechanical rotor speed of 1500 rpm.

(i) Calculate the magnitudes of the space-vector current $I_{ms,pk}$, the stator direct-axis current i_{sd} and quadrature-axis current i_{sq}, and the three phase currents, i_a, i_b, and i_c, to establish the rated flux at $t = 0^-$, the instant just before injection of a step current to develop rated torque.
(ii) Recalculate the above currents required to establish the rated flux and motoring torque at $t = 0^+$.
(iii) Assuming that the rotor speed is constant at 1500 rpm, calculate the per-phase currents at t = 5 ms.
(iv) Recalculate the above currents required to establish the rated flux and generating torque at $t = 0^+$.
(v) Assuming that the generator speed is constant at 1500 rpm, calculate the input electrical frequency and the per-phase currents at t = 5 ms.

[Ans. (i) 225 A, 183.7 A, 0 A, 150 A, -75 A, -75 A (ii) 477.3 A, 183.7 A, 343.7 A, 149.9 A, 168.1 A, -318 A (iii) –287.4 A, 261.9 A, 25.5 A (iv) 477.3 A, 183.7 A, -343.7 A, 149.9 A, -318 A, 168.1 A (v) 48.5 Hz, 287.4 A, -25.5 A, -261.9]

Summer 2004
Problem 3

In a 4-pole induction machine, a per-phase current of 46 Arms at an input electrical frequency of 200 Hz is required to establish the rated airgap flux density. A per-phase current of 93 Arms at an input electrical frequency of 202 Hz is required to establish rated motoring torque at a mechanical rotor speed of 6000 rpm.

(i) Calculate the magnitudes of the space-vector current $I_{ms,pk}$, the stator direct-axis current i_{sd} and quadrature-axis current i_{sq}, and the three phase currents, i_a, i_b, and i_c, to establish the rated flux at $t = 0^-$, the instant just before injection of a step current to develop rated torque.
(ii) Recalculate the above currents required to establish the rated flux and a re*generative* torque at $t = 0^+$.
(iii) Assuming that the generator speed is constant at 6000 rpm, calculate the input electrical frequency and the per-phase currents at t = 1.25 ms.

[Ans. (i) 97.7 A, 79.8 A, 0 A, 65.1 A, -32.5 A, -32.5 A, (ii) 197.3 A, 79.8 A, -139.9 A, 65.1 A, -131.5 A, 66.4 A; (iii) 198 Hz, 115.2 A, -2.8 A, -112.5 A]

Problem 4

Consider the Westinghouse 22 kW, four-pole machine with 400 V (line-line), 50 Hz applied in the delta configuration.

(i) Calculate the magnitudes of the space-vector current $I_{ms,pk}$, the stator direct-axis current i_{sd} and quadrature-axis current i_{sq}, and the three phase currents, i_a, i_b, and i_c, to establish the rated flux at $t = 0^-$, the instant just before injection of a step current to develop rated torque.

(ii) Recalculate the above currents required to establish the rated flux and motoring torque at $t = 0^+$.

(iii) Assuming rated rotor speed calculate the per-phase currents at $t = 2.5$ ms.

[Ans.]

Summer 2006

Problem 5

The specification table for the Westinghouse 30 kW, four-pole induction motor, with 400 V (line-line), 50 Hz applied in the delta configuration, is provided as an attachment (see page 6). Consider the machine running as an induction generator with a power electronics interface.

(i) Calculate the magnitudes of the space-vector current $I_{ms,pk}$, the stator direct-axis current i_{sd} and quadrature-axis current i_{sq}, and the three phase currents, i_a, i_b, and i_c, to establish the rated flux at $t = 0^-$, the instant just before injection of a step current to develop rated torque.

(ii) Recalculate the above currents required to establish the rated flux and generating torque at $t = 0^+$.

(iv) The generator speed is dropped to 1400 rpm, calculate the input electrical frequency and the per-phase currents at $t = 1$ ms when operating at rated torque and rated flux.

[Ans. (i) 29.66 A, 24.22 A, 0 A, 19.77 A, -9.89 A, -9.89 A (ii) 65.04 A, 24.22 A, 47.25 A, 19.78 A, -43.3 A, 23.53 A (iii) 45.5 Hz, 29.86 A, -42.16 A, -12.3 A]