EE 381 Machines Lab

EXPERIMENT - 8

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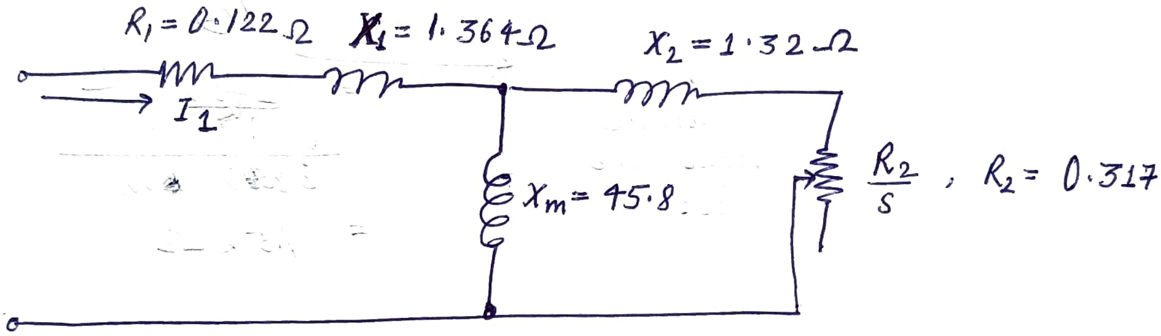
Title - Analysis of equivalent circuit of induction motor

Given quantities : 500 kW, 2400 V, 4 poles, 60 Hz induction machine

Equivalent circuit :



It is given that at slip of 3.35% the rated output shaft is achieved with an efficiency of 94.0%

Question(1) From the given data calculate the total rotational and core losses at rated load.

Total impedance $Z_{in} = (R_1 + jX_1) + (jX_m) \,||\, (jX_2 + \frac{R_2}{S})$

$\boxed{S = 0.0335}$

$$Z_{in} = (0.122 + j1.364) + \frac{(j45.8)(j1.32 + \frac{0.317}{0.0335})}{j45.8 + j1.32 + \frac{0.317}{0.0335}}$$

$$Z_{in} = (0.122 + j1.364) + (8.59 + j3.01)$$

$\boxed{Z_{in} = (8.72 + j4.37)}$ ohms
$= 9.754 \angle 26.617°$

$\boxed{Z = (8.59 + j3.01)}$ ohms

We know, $P_{air-gap} = n_{ph} I_1^2 R_f$

$I_1 = \frac{V_1}{Z_{in}} = \frac{\left(\frac{2400}{\sqrt{3}}\right)}{9.754 \angle 26.617}$ → per phase voltage.

$$\boxed{I_1 = 142.058 \angle -26.617^\circ}$$

$\Rightarrow P_{air-gap} = 3 \times (142.1)^2 (8.59)$
$= 520.358 \text{ kW}$

For rotational losses : $P_{rot} = P_{mech} - P_{shaft}$

$= (1-s) P_{air-gap} - P_{shaft}$

$= (1-0.0335)(520.358) - 500$

$$\boxed{P_{rot} = 2.926 \text{ kWatt}}$$

For core losses : $P_{core} = P_{in,no-core} - P_{in,core}$
(Input power without core-loss) (Input power with core loss)

$P_{in,no-core} = \frac{P_{out}}{\eta}$
$= \frac{500 \text{ kW}}{0.94}$
$= 531.91 \text{ kW}$

$P_{in,core} = n_{ph} \, Re[V_1 I_1^*]$
$= 3 \left(\frac{2400}{\sqrt{3}}\right)(142.1) \times \cos 26.62^\circ$
$= 528.08 \text{ kW}$

$$\Rightarrow \boxed{P_{core} = 3.83 \text{ kW}}$$

Question (3) With wind turbine driving the induction machine at $s = -3.2\%$. (i) The electric power output in kW
(ii) η (efficiency)
(iii) Power factor at the machine terminals.

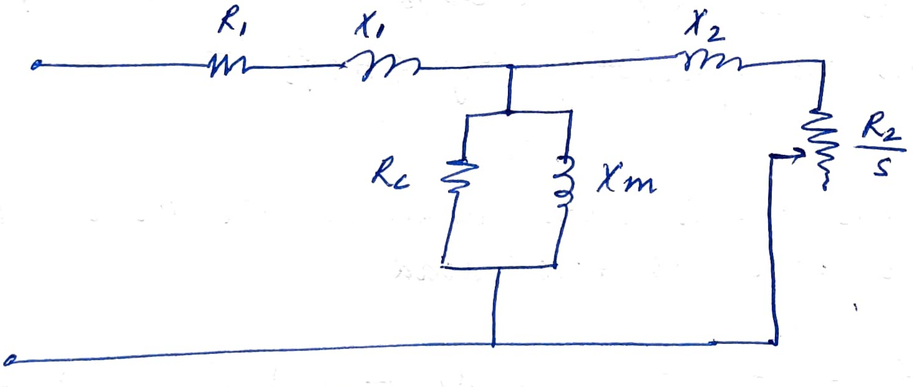
To add the core power loss $R_C = \frac{V_1^2}{P_{R_C}}$

To include total core loss

$$= \frac{(2400)^2}{3850 \text{ W}}$$

$$= 1.5\,k\Omega$$

Equivalent circuit :



At $s = -3.2\%$

$$Z_f = (jX_m \parallel R_c) \parallel (jX_m + \frac{R_2}{s})$$

$$= \left(\frac{(1500)(j45.8)}{1500 + j45.8}\right) \parallel \left(j1.32 - \frac{0.317}{0.032}\right) \quad 9.9$$

$$= \begin{matrix} -74.22 \\ -j451.08 \end{matrix}$$

$1.397 + j45.75$ $\frac{(1500)(j45.8)}{1500 + j45.8} + j1.32 - \frac{0.317}{0.032} = -8.50 + j47.07$

$1.397 + j45.75$

$$\boxed{Z_f = (-9 + j3.2)\,\Omega}$$

$$Z_{in} = Z_f + R_1 + jX_1$$
$$= (-9 + j3.2) + (0.122 + j1.364)$$
$$\boxed{Z_{in} = (-8.88 + j4.57)\ \Omega}$$

Here, stator current $I_1 = \dfrac{\left(\frac{2400}{\sqrt{3}}\right)}{-8.88 + j4.57} \rightarrow 9.98\angle 152.$

$$= \frac{1385.64}{9.98\angle 152.77^\circ}$$
$$\boxed{I_1 = 138.84\angle -152.77^\circ A}$$

$$P_{air-gap} = n_{ph} I_1^2 R_f$$
$$= -3(138.84)^2(9)$$
$$= -518.15\ kW$$

$$P_{in} = -P_{mech} + P_{rot}$$
$$= -(1-s)P_{gap} + P_{rot}$$
$$= +(1+0.032)\,518.15 + 3.5$$
$$\boxed{P_{in} = 538.22\,kW}$$

$$P_{out} = -n_{ph}\,Re[V_1 I_1^*]$$
$$= -3 \times \frac{2400}{\sqrt{3}} \times 138.53 \cos 157.78^\circ$$
$$\boxed{P_{out} = 512\ kW}$$

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100 = \frac{512}{538} \times 100$$
$$= 95.2\%$$

(1) Impedance of actual distribution system - $(0.18 + j0.41)$ Ω/phase

$s = -3.2\%$

$Z_{in} = (-8.88 + j4.57)\ \Omega$ /phase

Now stator current $I_1 = \dfrac{\left(\frac{2400}{\sqrt{3}}\right)}{(0.18 + j0.41) + (-8.88 + j4.57)}$

$= \dfrac{1385.64}{-8.70 + j4.98}$ → $10.02 \angle 150.21$

$= 138.28 \angle -150.21°$ A

$P_{out} = -n_{ph}\ Re[\bar{V}_1 \bar{I}_1^*]$

(At infinite bus) $= -3\left(\frac{2400}{\sqrt{3}}\right)(138.28)\cos(-150.21°)$

$\boxed{P_{out} = 498.5\,kW}$

Total power. $P_{machine} = P_{out} + n_{ph} I_1^2 R_{feeder}$

$= (498.5\,kW) + 3(138.28)^2(0.18)$

$\boxed{P_{machine} = 509\,kW}$