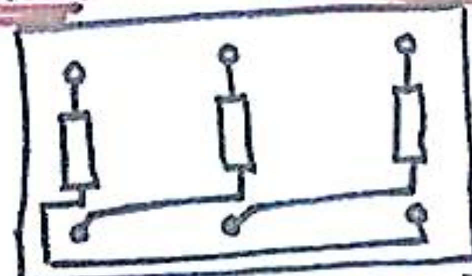
Tests of
3-ph Induction "Asynchronous" Motor

- dc Test
- Short circuit
- open circuit

Given 3-φ IM Squirrel Cage Type



Motor Connection Box

Nameplate:

Y-Connec. : 380V

Δ-Connec. : 220V, 2.1A

يقصد عند توصيل ملفات الـ STATOR يجب تطبيق القيم الموجودة هنا

Squirell Cage Rotor

Objective: Determine Values of Motor Parameters:

- R_1 : Stator resistance/ph.
- X_1 : " reactance/ph.
- R_2' : Rotor resistance/ph. (referred to stator side)
- X_2' : " reactance/ph. (referred to stator side)

R_c : magnetization resistance "due to hysteresis & eddy curr"

X_m : magnetization reactance

- P_{sc} : Short circuit losses "motor Cu. losses".
- P_{oc} : open circuit losses "hysteresis & eddy current losses"

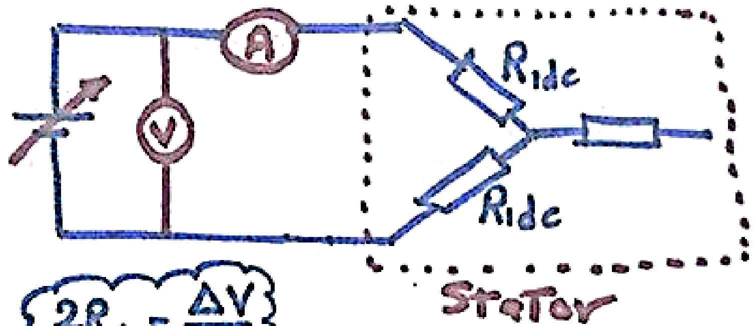
" The Same Motor is Used in All Tests "

Dc Test	Short Circuit "Blocked Rotor" Test	Open Circuit "No-load" Test
R_1	R_2' , X_1 , X_2' , P_{sc}	R_c , X_m , P_{oc}

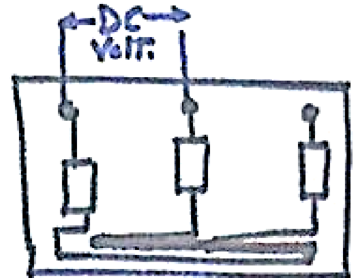
DC Test

Objective: R_1

Components:
- Ammeter
- Voltmeter
- Variable DC supply
- Connection Cables.



$$2R_{1dc} = \frac{\Delta V}{\Delta I}$$



Connect. Stator as Y- Conn.

Steps:

1. Connect Stator Terminals as Y- Connection.
2. Make sure that you adjust the supply at 0^V.
3. Connect the circuit to the supply as shown above.
4. Complete the following table by varying supply voltage.

- The final value "V_*" you apply from supply must be less than 10% of the rated voltage at Y- Connection:

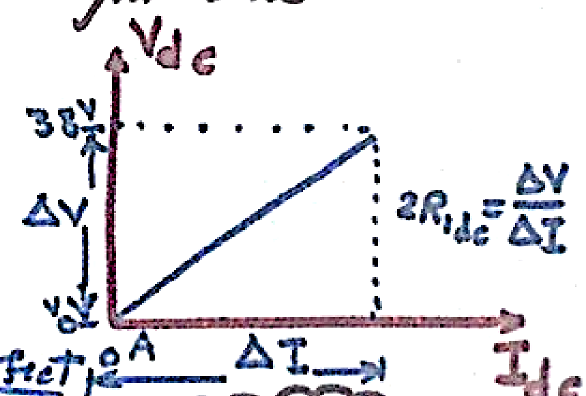
V_{dc} applied Voltage	0^V	5^V	10^V	.....	V_*
I_{dc} applied Current	...A	...A	...A	.....A	...A

$V_* \leq 10\% * 380 \longrightarrow 38^V$

5. draw the relation betn V_{dc} & I_{dc} is straight line.

$$\therefore 2R_{1dc} = \frac{\Delta V}{\Delta I} = \dots \Omega$$

but $\boxed{R_{1ac} = 1.2\, R_{1dc} = \dots \Omega}$



" Value of R_1 is R_{1ac} ".

$(R_1 = R_{1ac}) > (R_{1dc})$ due to **Skin Effect**:

مساحة المقطع التي تقوم بمرور التيار في حالة الـ (ac) تكون أقل من مساحة المقطع في حالة (dc).

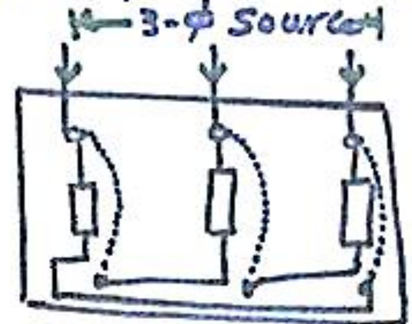
$$R = \rho \cdot \frac{L}{A}$$

Short-Circuit OR Blocked Rotor Test

Objective: R_2' & X_1 & X_2' & P_{sc}

Components:
- Ammeter & Voltmeter & Wattmeter
- Variable 3-φ ac supply.
- Connection Cables
- Iron Rod: To block the rotor from rotation

Motor eq't circuit per phase referred to stator side at $s=1$



Δ-Conn. Stator

" $R_c \parallel jX_m$ is very high so it is open "

Steps:

① Connect the stator terminals as Δ, Block the rotor using Iron Rod

② Make sure that your supply voltage is 0^V.

③ Connect the circuit of the motor as above

④ Increase supply voltage until the short circuit current value is passes through the motor. $I_{sc} = \frac{I_r}{\sqrt{3}} = \frac{2.1^A}{\sqrt{3}} = 1.2^A$

⑤ Complete the following Table:

Ammeter reading (A)	Voltmeter Reading (V)	Wattmeter reading (Watt)
$I_{sc} = 1.2$ A	$V_{sc} = \dots$ V	$P_{sc} = \dots$ Watt

$\because P_{sc} = 3 V_{sc} I_{sc} \cos\phi_{sc}$ $\quad \therefore \cos\phi_{sc} = \dots$

$P_{sc} = 3 I_{sc}^2 \cdot R_{sc}$ $\quad \therefore R_{sc} = \dots \Omega = R_{1eq}$

$\therefore R_{1eq} = R_1 + R_2'$ (R_1 → DC Test) → $\therefore R_2' = \dots \Omega$ $\quad P_{sc} = \dots$ Watt

$Z_{1eq} = \frac{V_{sc}}{I_{sc}} = \dots \Omega \longrightarrow X_{1eq} = \sqrt{Z_{1eq}^2 - R_{1eq}^2} = \dots \Omega$

$X_{1eq} \simeq 2X_1 \simeq 2X_2'$ "i.e: $X_1 = X_2'$"

$X_1 = X_2' = \frac{X_{1eq}}{2} = \dots \Omega$

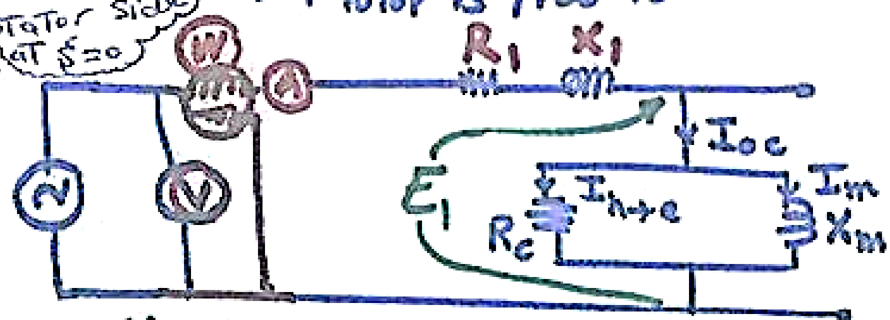
Note: $S = \frac{N_s - 0}{N_s} = \frac{N_s}{N_s} = 1$

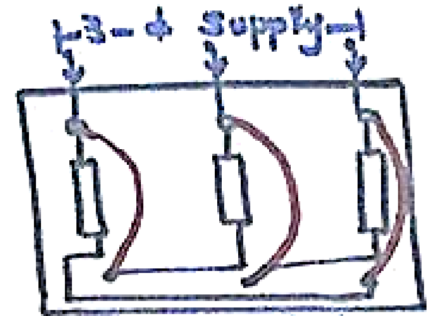
Open-Circuit = No-load Test

Objective: R_c & X_m & P_{oc}

Components:
- Ammeter & Voltmeter & Wattmeter
- Variable 3-ϕ ac supply.
- Connection Cables
- Motor is free to rotate & has no-load.

(eq. circuit per phase referred to stator side at $s=0$)





Δ-Conn. stator

" $s = \frac{N_s - N}{N_s} = \frac{0}{N_s} = 0 \rightarrow \frac{R_2'}{s} = \infty$ " o.c "

Steps:

1. Connect stator terminals as Δ, Rotor is free to rotate and has no-load.
2. Make sure that your supply voltage is 0^V.
3. Connect the circuit as above.
4. Increase supply voltage until the applied voltage from supply is 220^V.
5. Complete the following table.

Ammeter reading (A)	Voltmeter reading (V)	Wattmeter reading (Watt)
I_{oc} = ... A	$V_{oc} = 220^V$	P_{oc} = ... Watt

P_{oc} = ... Watt

$P_{oc} = 3 V_{oc} I_{oc} \cos\phi_{oc}$

$\therefore \cos\phi_{oc}$ = ... & $\sin\phi_{oc}$ = ... & ϕ_{oc} = ...

$\overline{I_{oc}} = |I_{oc}| \angle -\phi_{oc}^\circ$ = ... $\angle$ .... A

$\overline{E_1} = \overline{V_{oc}} - \overline{I_{oc}} (R_1 + jX_1)$ ....> R_1 & X_1 from short circuit test

$= 220\angle 0^\circ - |I_{oc}| \angle -\phi_{oc}^\circ (R_1 + jX_1)$

$= |E_1| \angle ....^\circ$ Volts

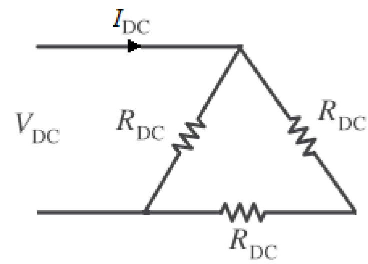
$R_c = \frac{E_1}{I_{h+e}}$ & $X_m = \frac{E_1}{I_m}$

$I_{h+e} = I_{oc} \cos\phi_{oc}$ = ... A

$I_m = I_{oc} \sin\phi_{oc}$ = ... A

Example: A dc test is performed on a 460V, Δ-connected 100hp induction motor. If V_{DC}=24V and I_{DC}=80A, what is the ac stator resistance R_1.

Answer



$$R_{tot} = \frac{2R_{DC} \times R_{DC}}{R_{DC} + R_{DC} + R_{DC}} = \frac{2R_{DC}}{3}$$

$$V_{DC} = \frac{2R_{DC}}{3} \times I_{DC} \quad \rightarrow \quad 24 = \frac{2R_{DC}}{3} \times 80 \quad \rightarrow R_{DC} = 0.45$$

$$R_1 = 1.2 \times R_{DC} = 1.2 \times 0.45 = 0.54\Omega$$

Example: A 208V, 60Hz, six-pole, Y-connected 25hp design class B induction motor is tested in the laboratory, with the following results:

No load : 208 V, 22.0 A, 1200 W, 60 Hz
Locked rotor: 24.6 V, 64.5 A, 2200 W, 15 Hz
DC test : 13.5 V, 64 A

Find the equivalent circuit parameters: R_1, X_1, R'_2, X'_2, R_c, X_M
(assume: $R_1 = 1.2\, R_{DC}$, $X_1 = X'_2$)

Answer

DC test: (Y - connected stator)

$$2R_{DC} = \frac{V_{DC}}{I_{DC}} = \frac{13.5}{64} \quad \rightarrow \quad R_{DC} = 0.1055\Omega \quad \rightarrow \quad R_1 = R_{DC} = 0.1055\Omega$$

Short - circuit :

$$\because P_{sc} = 3I_{sc}^2 R_{1eq}$$

$$2200 = 3 \times 64.5^2 \times R_{1eq}$$

$$R_{1eq} = 0.1763 = R_1 + R'_2 \quad \rightarrow \quad 0.1763 = 0.1055 + R'_2 \quad \rightarrow \quad R'_2 = 0.071\Omega$$

$$\because Z_{1eq} = \frac{V_{sc}}{I_{sc}} = \frac{24.6/\sqrt{3}}{64.5} = 0.2202\Omega$$

$$X_{1eq} = \sqrt{Z_{1eq}^2 - R_{1eq}^2} = \sqrt{0.2202^2 - 0.1763^2} = 0.132\Omega \quad \rightarrow \quad X_1 = X'_2 = \frac{0.132}{2} = 0.066\Omega$$

Open - circuit :

$$\because P_{oc} = 3V_{oc} I_{oc} \cos\phi_{oc}$$

$$1200 = 3 \times \frac{208}{\sqrt{3}} \times 22 \times \cos\phi_{oc} \quad \rightarrow \quad \cos\phi_{oc} = 0.154 \quad and \quad \phi_{oc} = 81.3^o \quad and \quad \cos\phi_{oc} = 0.988$$

$$\therefore \overline{I_{oc}} = I_{oc}\angle -\phi_{oc} = 22\angle -81.3^o\, A$$

$$\therefore \underline{I_{h+e} = I_{oc}\cos\phi_{oc} = 22 \times 0.154 = 3.3308A} \quad and \quad \underline{I_M = I_{oc}\sin\phi_{oc} = 22 \times 0.988 = 21.736A}$$

$$\because \overline{E_1} = \overline{V_{oc}} - \overline{I_{oc}}(R_1 + jX_1)$$

$$= 220\angle 0^o - 22\angle -81.3^o (0.1055 + j0.066)$$

$$= 220\angle 0^o - 2.728\angle -49.3^o$$

$$= 118.22\angle -2.1^o\, V$$

$$\therefore R_c = \frac{E_1}{I_{h+e}} = \frac{118.22}{3.3308} = 35.3\Omega$$

$$\therefore X_M = \frac{E_1}{I_M} = \frac{118.22}{21.736} = 5.44\Omega$$