Motor operations and characteristics.

Star delta

- When motor reaches about 80% of its full load speed, it begins to run in delta connection Stator winding.
- The star delta is used to reduce starting current of the motor

V_L – Supply line voltage
I_{LS} – Supply line current
I_{ps} – phase current
Z – Impedance per phase

- In star connection

$$I_{ps} = I_{LS}$$

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$

$$I_{ps} = \frac{V_L}{\sqrt{3}\,Z}$$

$$I_{ps} = \frac{V_L}{\sqrt{3}\,Z} \Leftrightarrow I_{LS} = \frac{V_L}{\sqrt{3}\,Z}$$

- Delta connection

I_{LD} – line current
I_{pD} – phase current
Z – phase impedance

In delta

$$I_{LD} = \sqrt{3}\, I_{pD}$$

$$V_L = V_{ph}$$

$$\therefore\ I_{pD} = \frac{V_L}{Z}$$

$$I_{LD} = \sqrt{3}\, I_{pd} = \frac{\sqrt{3} V_L}{Z}$$

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← motor speeds

speed	2680	5360
delta torque / speed	0.5 / 2910 =	1 / 5620

✓ Thus motors in delta connection have a speed torque - speed ratio than those running in star

✓ Moreover, they are able to hit higher speeds than those in star connection

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Ratio of line current drawn in star connection versus line current drawn in delta connection

$$\frac{I_{LD}}{I_{LS}} = \frac{\frac{\sqrt{3}V_L}{Z}}{\frac{V_L}{\sqrt{3}Z}} = 3$$

$$I_{LS} = \frac{1}{3} I_{LD}$$

⇒ The starting mains line current in star is $\frac{1}{3}$ the starting mains line current in delta.

Similarly, Starting torque is proportional to square of phase voltage applied

Thus $\frac{\text{Starting torque in star connection}}{\text{Starting torque in delta connection}}$

$$= \frac{\left(\frac{V_L}{\sqrt{3}}\right)^2}{V_L^2} = \frac{1}{3}$$

⇒ The star delta reduces the starting torque by $\frac{1}{3}$ times.

From Data. (star connection)

M/Nm	0·0	0·1	0·3	0·5	0·7	0·9
n (1/rpm)	2930	2890	2800	2680	2520	2220
U phase /V	225	225	225	225	225	225
I phase /A	0·16	0·20	0·26	0·40	0·53	0·74

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Analysis

STAR

Line current = 0.6A

line voltage = 690V

Operating speed = 2800 rpm

V_{phase} (max) = 400V

V_{star} = 224.6V I_{phase} = 0.167A

Table : (practical)

M/Nm	0.0	0.1	0.3	0.5	0.7	0.9
N/(rpm)	3130	2890	2800	2680	2520	2320
V phase	225	225	205	205	225	225
I phase	0.16	0.20	0.20	0.40	0.53	0.74

→ table 1

V_L = 690V

V_{ph} = 400V

$V_L : V_{ph} = \frac{690}{400} = 1.725$

Theoretical :

$V_L = \sqrt{3} V_{ph}$

$690 = \sqrt{3}\ 400$

Ratio = $\sqrt{3}$

= 1.732

As the torque increases from 0 N/m to 0.9 N/m, the operating current increases from 0.16 to 0.74 Thus as torque increases, more current is drawn by the motor

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Delta connection

N/Nm	0·0	0·5	1·0	1·5	2·0	2·5
n/rpm	2975	2910	2830	2744	2600	2370
V/phase (V)	389	389	389	389	389	389
I phase (A)	0·29	0·35	0·46	0·60	0·81	1·09

$V_L = 400\,V$ } Experimental
$V_{ph} = 389\,V$ }

$V_L \approx V_{ph}$ → Theoretical

$I_L = 1A$ $\quad I_L : I_{ph} = 1.887$ (experimental)

$I_{ph} = 0.53$

$I_L = \sqrt{3}\, I_{ph}$ $\quad I_L : I_{ph} = 1.732$ (Theoretical)

Comparisons

(i) **At torque of 0·5 Nm**

Star
operating speed = 2680
Current drawn = 0.40

Delta:
operating speed = 2910
Current drawn = 0.35

→ Thus at the same torque, a motor running in delta runs at at a more speed (2910) than one running in star (2680)

(ii) **Starting currents** (at 0 Nm)

star : 0·16
delta : 0·29
} Phase currents

Thus $\dfrac{I_{L(star)}}{I_{L(delta)}} = \dfrac{0.16}{\sqrt{3} \times 0.29} = 0.3186$

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Theoretical :

$$\frac{I_{L\,(star)}}{I_{L\,(delta)}} = \frac{1}{3} = 0.3333$$

Maximum | operating torque

Star (at 0.9 N/m)
delta (at 2.5 N/m)

$$\frac{\text{torque star}}{\text{torque delta}} = \frac{0.9}{2.5} = 0.36$$

$$\frac{\text{Theoretical}}{\frac{\text{Torque star}}{\text{Torque delta}}} = \frac{1}{3} = 0.3333.$$

∴ ✓ Thus, the starting current in star is $\frac{1}{3}$ the starting current in delta.

✓ The motor running in delta attains higher speeds at the same torque level as the ones running in star at same torque speed (2910 at 0.5 N/m vs 2680 at 0.5 N/m)

(2) Torque speed curves

at 0.5 N/m

Star: $\frac{\text{Torque}}{\text{speed}} = \frac{0.5}{2680} = \frac{1}{5360}$

delta $\frac{\text{torque}}{\text{speed}} = \frac{0.5}{2910} = \frac{1}{5620}$

✓ Their motors in delta connection have a speed torque - speed ratio than those running in star

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