Prepared by J.R Nayak

Speed Control of 3-ϕ IM

$N_r = N_s(1-s)$ | $\omega_r = \omega_{sm}(1-s)$

$= \frac{120f}{P}[1-s]$ | $\omega_r = \frac{4\pi f}{P}(1-s)$

$$N_r = \frac{120f}{P}(1-s)$$

- f → Frequency Control
- (1 − s) → slip control method
- P → Pole changing methods of speed control

→ Speed of IM can be controlled either by controlling slip or by pole or by frequency.

Slip control can be achived in two ways

(i) voltage control method of slip control

(ii) Rotor resistance control method of slip control.

Voltage control method of speed control

In this method variable voltage at constant frequency being supplied to the motor stator.

Torque in operating zone [Low slip zone]

$$T = \frac{3}{\omega_s} \times \frac{V_{ph}^2}{R_2'} \times s$$

$$\boxed{T \propto V^2 s}$$

Note For constant load torque

$V^2 \times s$ = constant

$$\boxed{s \propto \frac{1}{V^2}}$$

$$T = \frac{3}{\omega_s} (I_2')^2 \frac{R_2'}{s}$$

$$T \propto \frac{(I_2')^2}{s}$$

Note

For constant torque load

$(I_2')^2 \propto s$

* If slip needed to be doubled then voltage needed to be reduced by $\frac{1}{\sqrt{2}}$ times in voltage control method and the corresponding rotor current rises to $\sqrt{2}$ times for constant torque load. The motor is therefore gets heated. This method is therefore rarely used for controlling speed of 3-ϕ IM.

* This method is useful for motor driving fan type load for which load torque is proportional to N^2.

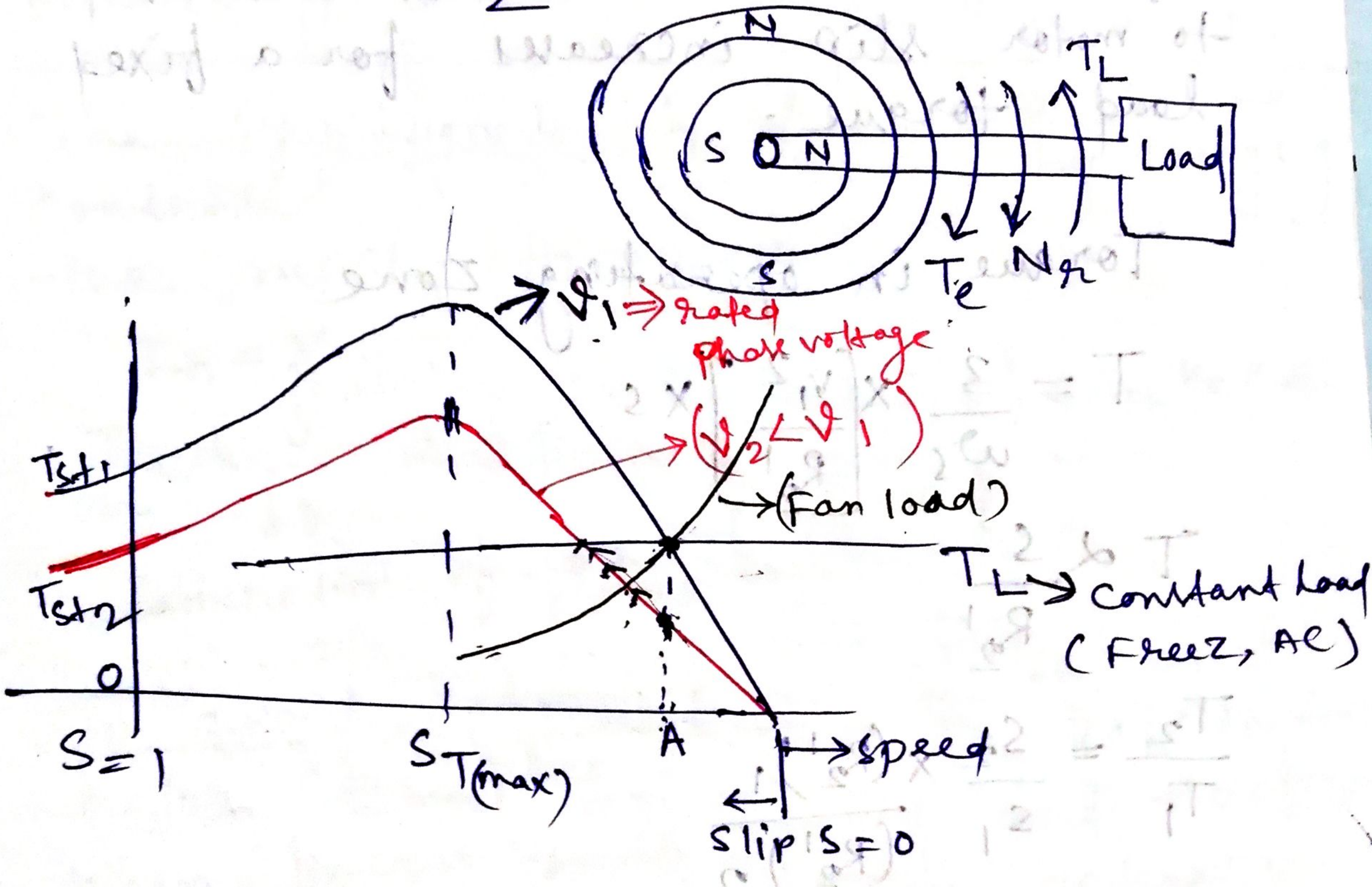
$$\boxed{T_L \propto N^2}$$ Fan type load

(i) $T_{max} = \frac{3}{\omega_s} \frac{E_2^2}{2X_2}$

(ii) $T_{\text{in low slip}} = \frac{3}{\omega_s} \frac{E_2^2}{R_2} s$

(iii) T in high slip zone $= \frac{3}{\omega_s} \frac{E_2^2}{X_2^2} \times \frac{R_2}{S}$

(v) $S_{T(max)} = \frac{R_2}{X_2}$



Let to decrease speed we decrease voltage so, for constant load torque, Te decreases.

$$\uparrow S = \frac{N_s - N_r\downarrow}{N_s}$$

so, in operating region Te increases

It setteled at $T_e = T_L$

For fan type load no problem as with decrease in voltage torque demand also decreases.

This is used where starting torque is low and with increase in speed torque increases.

Rotor resistance Control Method

→ This method of speed control is useful only for slip ring induction motor.

→ If the rotor resistance is increased to motor slip increases for a fixed load torque.

Torque in operating zone

$$T = \frac{3}{\omega_s} \times \left[\frac{V_1^2}{R_2'}\right] \times s$$

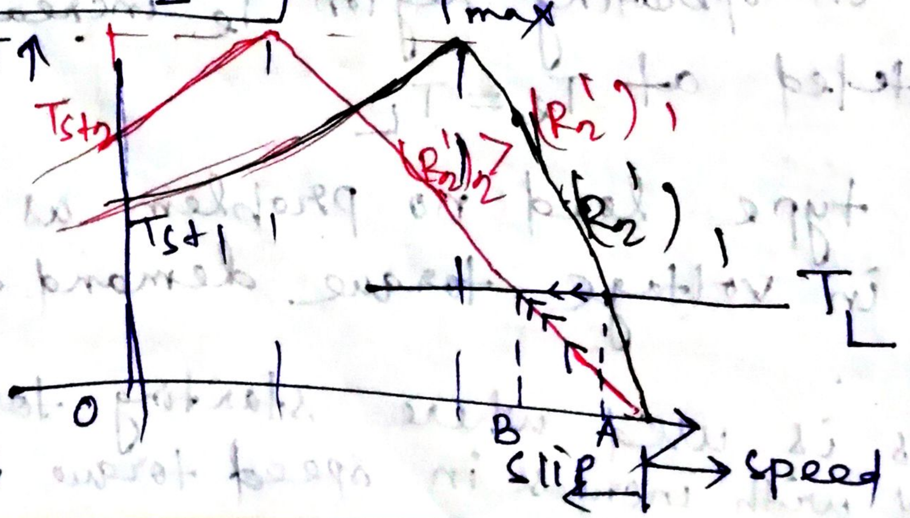
$$T \propto \frac{s}{R_2'}$$

$$\frac{T_2}{T_1} = \frac{s_2}{s_1} \times \frac{(R_2')_1}{(R_2')_2}$$

For Constant torque load

$$\frac{s}{R_2'} = \text{Constant}$$

$$\boxed{s \propto R_2'}$$



→ Due to resistive loss this method of speed control used to control speed in very narrow speed range.

Frequency control method of speed control

The synchronous speed of IM can be controlled in a wide range by changing the supply frequency.

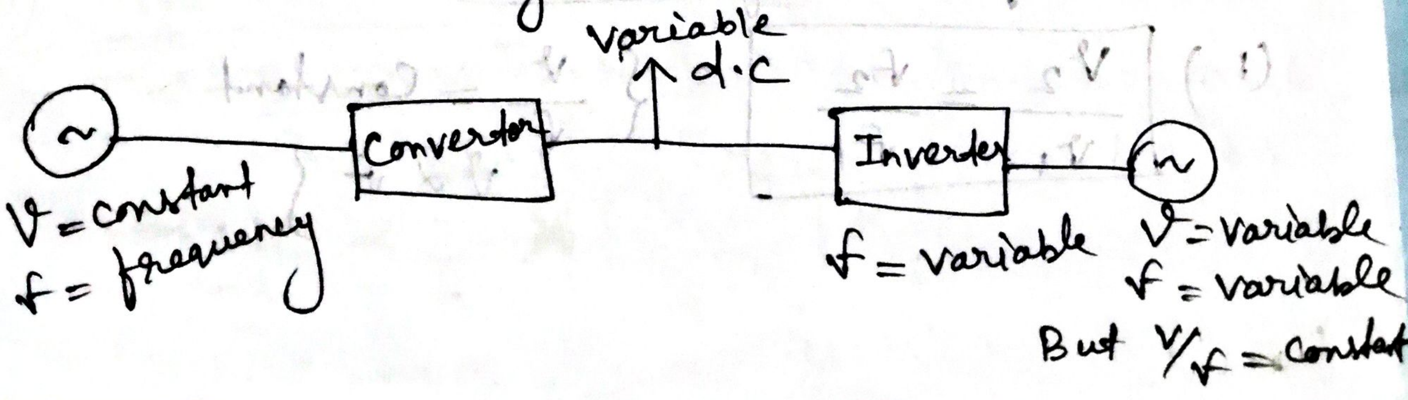
$I_m = \frac{V}{X_m}$

$I_m \propto \frac{V}{\downarrow f} \propto \phi \uparrow$ $\left\{ \begin{array}{l} V = \sqrt{2}\pi f \phi T_{ph} K_c K_d \\ \frac{V}{f} \propto \phi \end{array} \right.$

Saturation of core occure

To avoid saturation in stator and rotor core flux ϕ must be kept constant when frequency is varied and therefore frequency control method is actually $\frac{V}{f}$ control method.

Variable (V, f) supply can be arranged from constant (V, f) supply by convertor-inverter arrangement shown below.



f↓ then at same slip T↑ In high slip Zone.

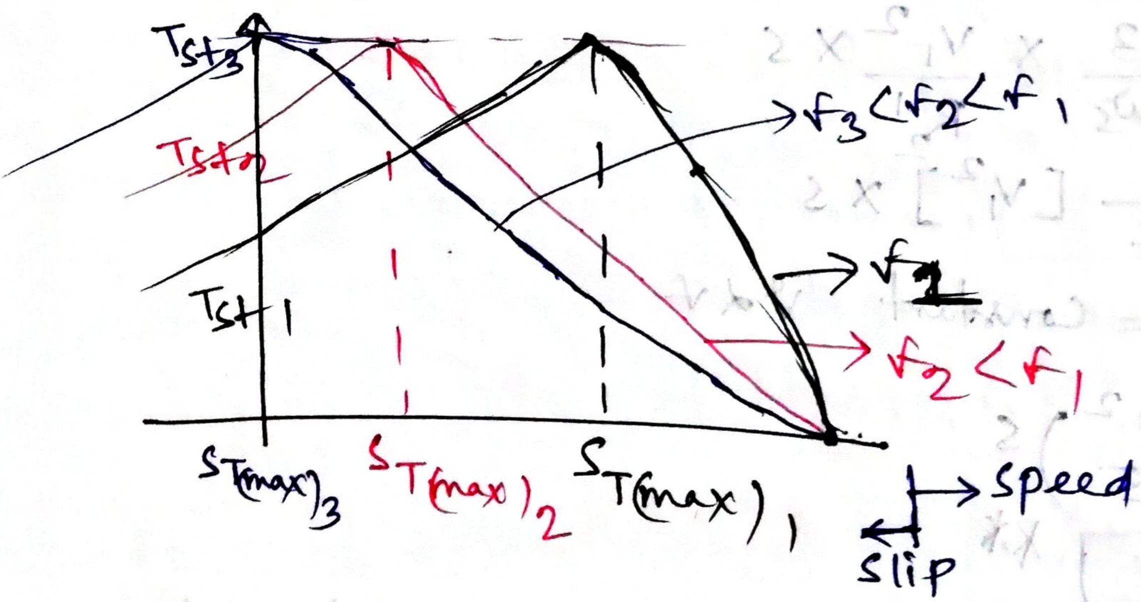
(iii) $T_{(max)} = \frac{3}{\omega_s} \frac{V_1^2}{2X_2}$

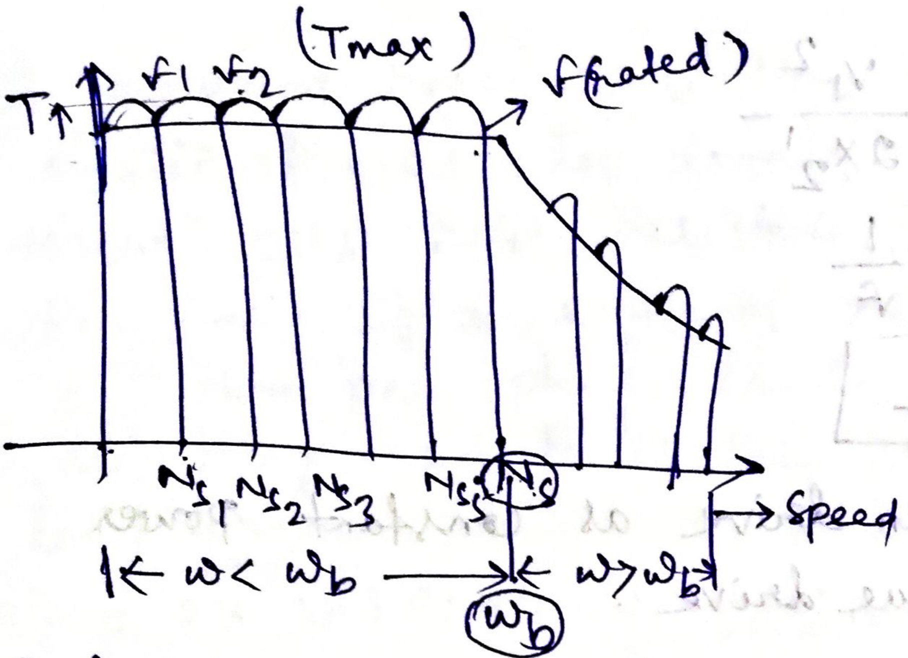
$T_{(max)} \propto \frac{1}{f}\left[\frac{f^2}{f}\right]$

T_{max} = Constant

till $\frac{V}{f}$ = constant

But the slip at which torque is max^m changes $\boxed{\uparrow S_{T(max)} \propto \frac{1}{f\downarrow}}$





↑P = T ω ↑ (T → constant)

$T = \frac{P \uparrow}{\omega \uparrow}$

P = T↓ ω↑ (P → constant)

Below base speed (ω < ωb)

This speed region is called subsynchronous speed region and in this speed region $\frac{V}{f}$ ratio is constant so that maximum motor torque is constant and therefore in this speed region motor can drive as constant torque variable power drive.

$$P = T \times \omega$$

If torque constant $P \propto \omega$

Above Base speed (Super synchronous speed)

Voltage "V" needed to keep $\frac{V}{f}$ = Constant is more than rated voltage which cannot be supplied by converter and therefore in this speed zone $\frac{V}{f}$ is allowed to change.

$$\uparrow \frac{V}{f} \propto \phi \downarrow$$

$$T_{max} = \frac{3}{\omega_s} \times \frac{V_1^2}{2X_2'}$$

$$T_{max} \propto \frac{1}{f} \times \frac{1}{f}$$

$$\boxed{T_{max} \propto \frac{1}{f^2}}$$

i,e motor can drive as constant power variable torque drive.

Note Torque in operating zone

$$T = \frac{3}{\omega_s} \left[\frac{V_1^2}{R_2'}\right] \times s$$

$$T \propto \frac{1}{f} \times [f^2] \times s$$

$$\boxed{T \propto sf}$$

$$T = \frac{3}{\omega_s} (I_2')^2 \times \frac{R_2'}{s}$$

$$T \propto \frac{1}{f} \times \frac{(I_2')^2}{s}$$

$$\boxed{T \propto \frac{(I_2')^2}{sf}}$$

For constant torque load

$$\boxed{sf = \text{Constant}}$$

$(I_2') \propto sf$

i,e $I_2' =$ constant

Note

$\frac{V}{f}$ control method will have same torque speed characteristic as that of ward Leonard method of speed control of DC shunt and with V/f control Now a days IM are replacing all dc motors (Industrial).