1. Margin Angle Control of Wound Field Sm.

* Inner Current loop
* outer Speed loop

(ω_m) Sensed from With help of Rotor position Encoder. Actual Speed

The Comparator generates an Error in Speed Signal by Comparing reference Speed (ω_m^*) and Actual Speed (ω_m). The Speed Controller process their Error Signal and o/p from Speed Controller is given to Current limiter.

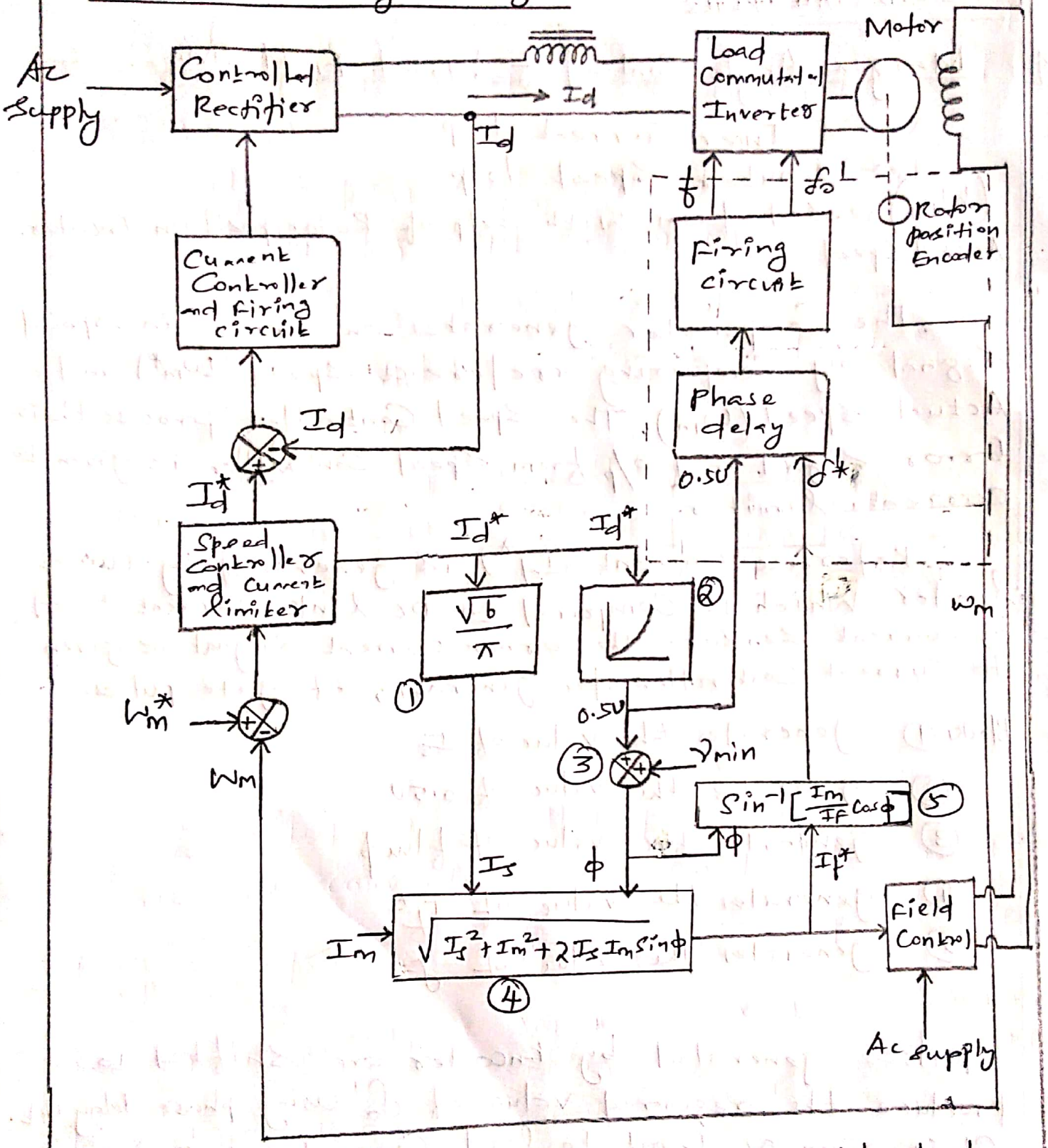
Reference Current (I_f^*) is generated by Current limiter Which is Compared to DC link current Sensed by Current Sensor. The error current signal is given to Current Controller for generation of gate pulses.

Block ① Generates the value of I_s
② Generates the value of 0.150
③ Generates the value of flux ϕ
④ generates the value of I_f^*
⑤ Generates the value of δ^*

pulses generated by Encoder are Shifted to produce the required value of δ_0' using phase delay Ckt. δ_0' is given as Input to load Commutated Inverter for proper tuning ON and OFF of thyristors.

Appl:
(i) High power and very High power drives.
(ii) High Speed drives blowers, Conveyers, Steel Mills, Fly Wheel Energy, Compressors
(iii) Gas Turbine and pumped Storage plants.

Constant Margin Angle:



Constant Marginal Angle Control is the best way to use Inverter and Motor in an Efficient Manner. The Maximum torque per ampere of the Armature current and the Highest power factor operation can be achieved by operating the Inverter at the minimum permissible value of Margin Angle.

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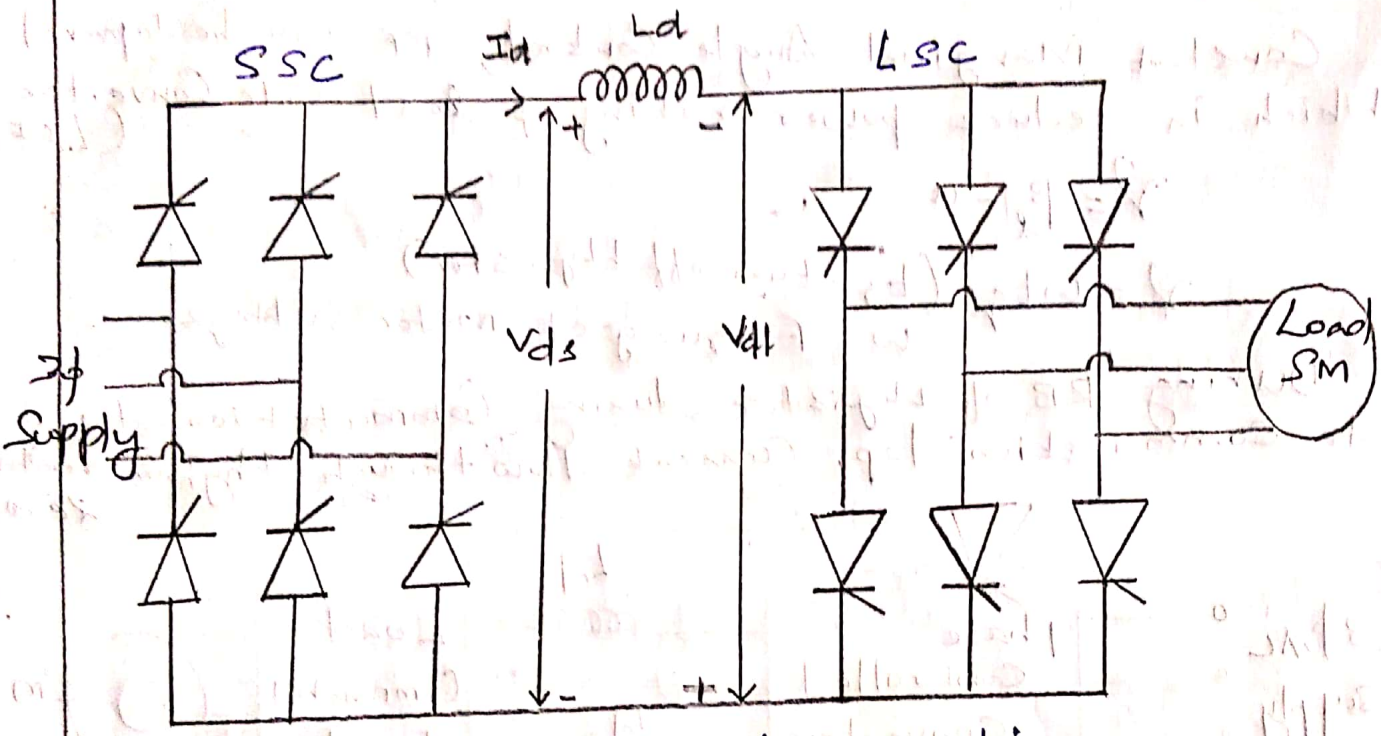
2. **Load Commutated Thyristor Inverter fed Synchronous Motor drive with Self Controlled operation:**

High power Appl → Wound Field SM

Medium power Appl → PM SM



LCI fed Self Controlled operation.

Source side Converter			Load side Converter		
Firing Angle	operation	o/p polarity	Firing Angle	operation	o/p polarity
$0 < \alpha_s < 90°$	Rectifier	Vdc(+) Idc(+)	$0 < \alpha_l < 90°$	Rectifier	Vdl(+) Idl(+)
$90° < \alpha_s < 180°$	Inverter	Vdc(-) Idc(+)	$90 < \alpha_l < 180°$	Inverter	Vdl(-) Idl(+)

Speed of the Synchronous Motor Can be Controlled by Varying firing angles of Source side Converter (α_s) & torque of the Synchronous Motor depends on $(V_{ds} - V_{dl})$

$\alpha < 180°$ to avoid commutation overlap

$\beta_l = 180° - \alpha_l$

Generally β_l is very small value and so the raking of the Inverter gets lowered for high power factor operation.

β_l = Constant value = LCI

$\beta_l = 180^\circ (\omega) 0^\circ$ = Rectifier

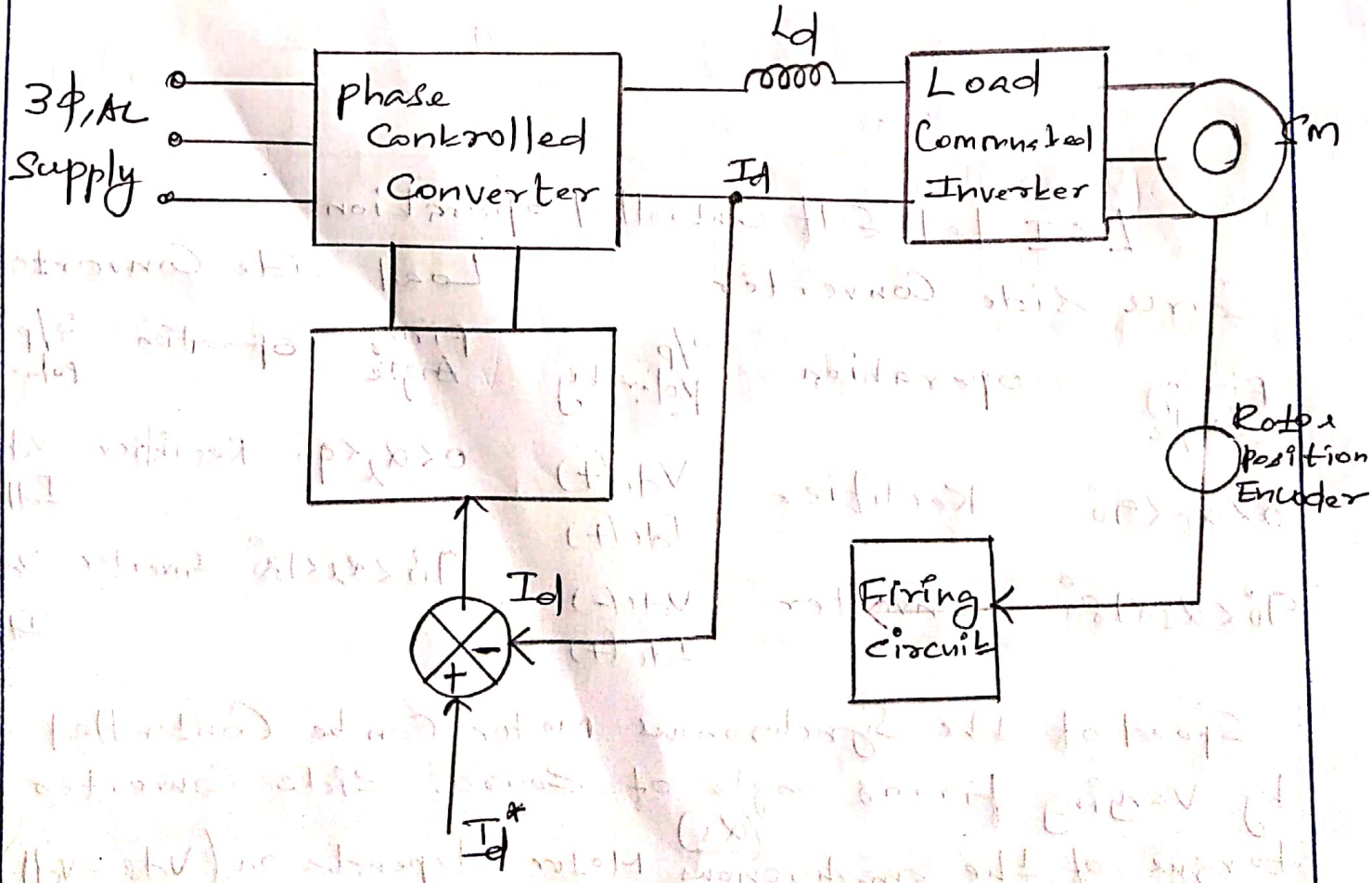
Constant Marginal Angle Control, PF can be Improved which in reduce power raking of load side Converter (LCI)

$\gamma = \beta_l - u$

$\gamma = \omega t_q$ (t_q - turn off thyristor)

ω - Frequency of motor voltage

During RB of thyristor during Commutation, due to Commutation lap, Current flow through thyristor reaches zero.



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3. V/f Control of Synchronous Motor drive:

(a) By maintaing V/f ratio Constant Synchronous Motor can be operated with Constant flux below base speed, as like an IM.

At Base speed, at once the rated terminal voltage is reached, the machine is operated at rated terminal voltage with variable frequency for High speed operation For Constant Flux operation, the pull out torque remains Constant and its gets decreased with increase in Frequency For High speed operation.

Synchronous motor runs Synchronous speed, Variable frequency Control can be Implemented either in Separate Control Mode (or) Self Control Mode.

V/f Separate Control:.. (Open loop)

An independent oscillator is used to Control the frequency of supply applied to stator.

Since there is a gradual increase in Initial value of frequency to the desired value, the diff b/w Synchro speed is very small all times. This support rotor to track the Variations in Synchronous speed.

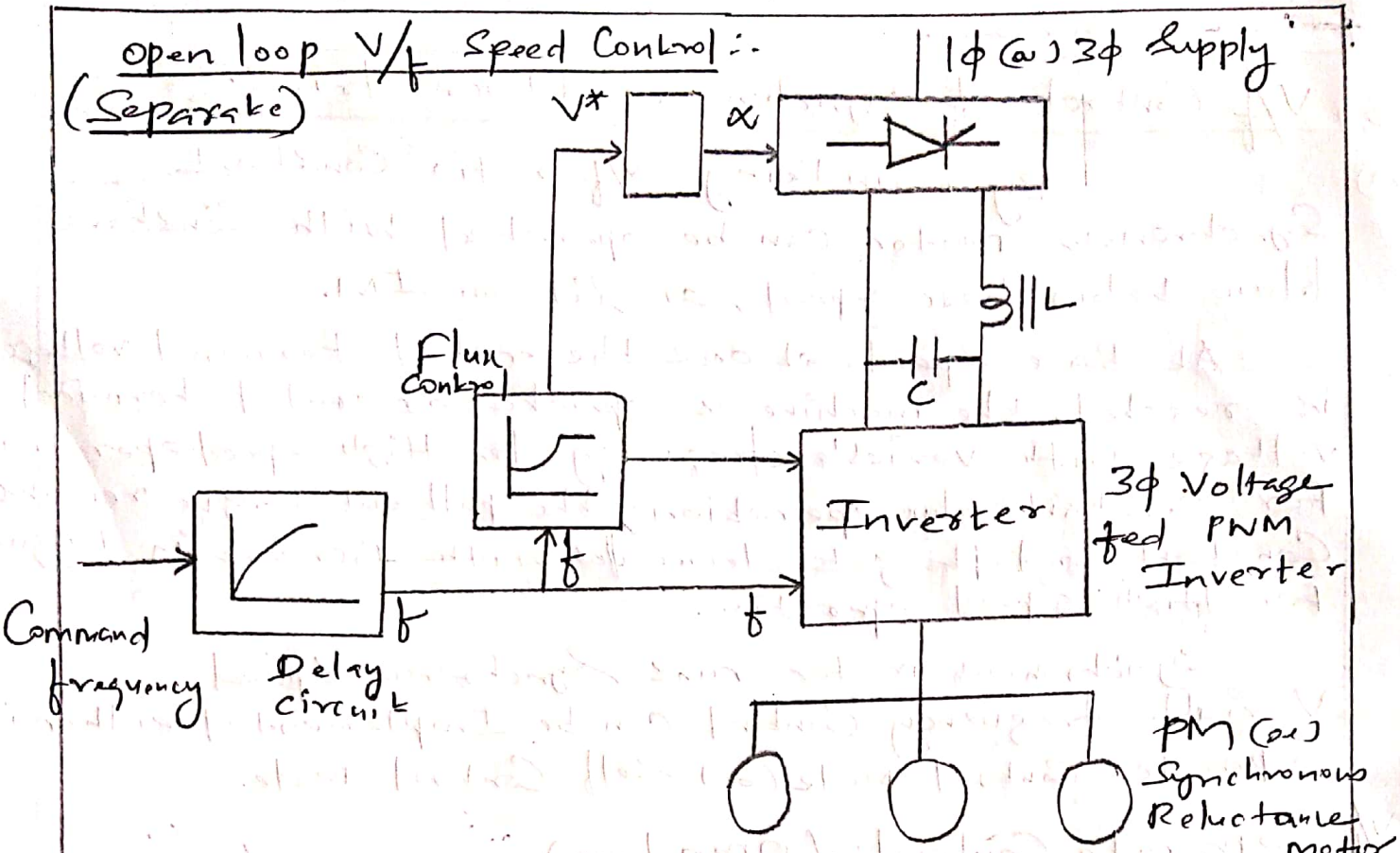
Once after the Synchronous speed is reached, the rotor experiences hunking oscillations and gets pulled into step (For Smooth starting and regenerative braking, Separate Control is very much Useful).

Delay ckt process the Frequency Command f^* and produces the desired frequency which is to be fed to PWM Inverter.

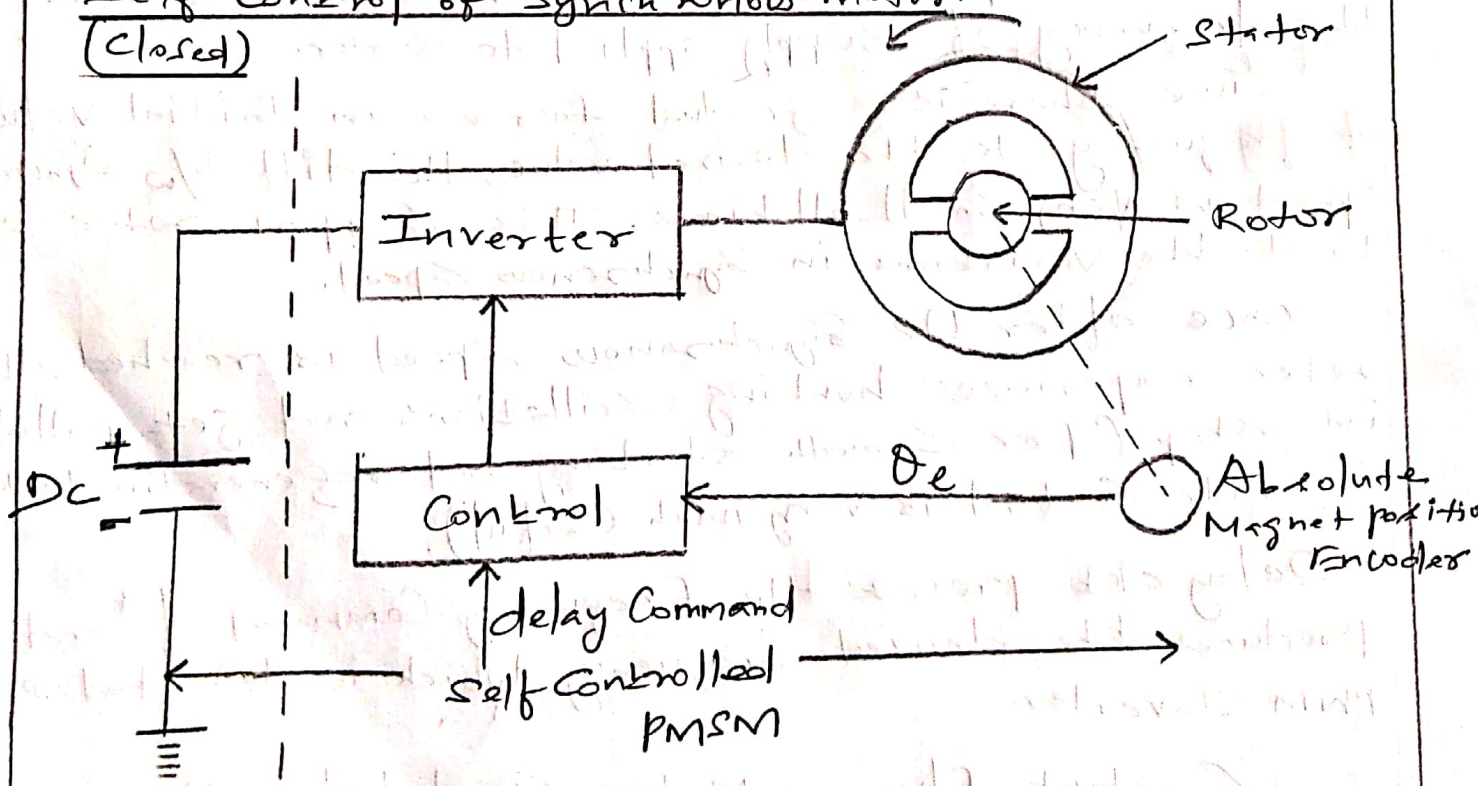
Constant flux Maintained — Motor speed below the Base speed

Constant terminal voltage — Motor speed above the Base speed.

Open loop V/f Speed Control :- (Separate)



Self Control of Synchronous Motor :- (Closed)



Self Controlled Synchronous Motor:

In Self Controlled Mode operation, Supply frequency is varied, In order to Synchronous Speed equal to the motor speed, Hunting oscillations can be avoided as rotor cannot pull out of step. Hence the Motor with Self control mode operation donot need any damper winding as in case of Separate Control.

Torque Angle and voltage/current decides the machine behaviour. This can be viewed as a DC Motor having a Converter Connected to the stator instead of its Commutator.

Self Controlled Motor can be called as Commutator less Motor (CLM) since the machine Exhibits Same characteristics of DC Motor under Steady State and dynamic Conditions.

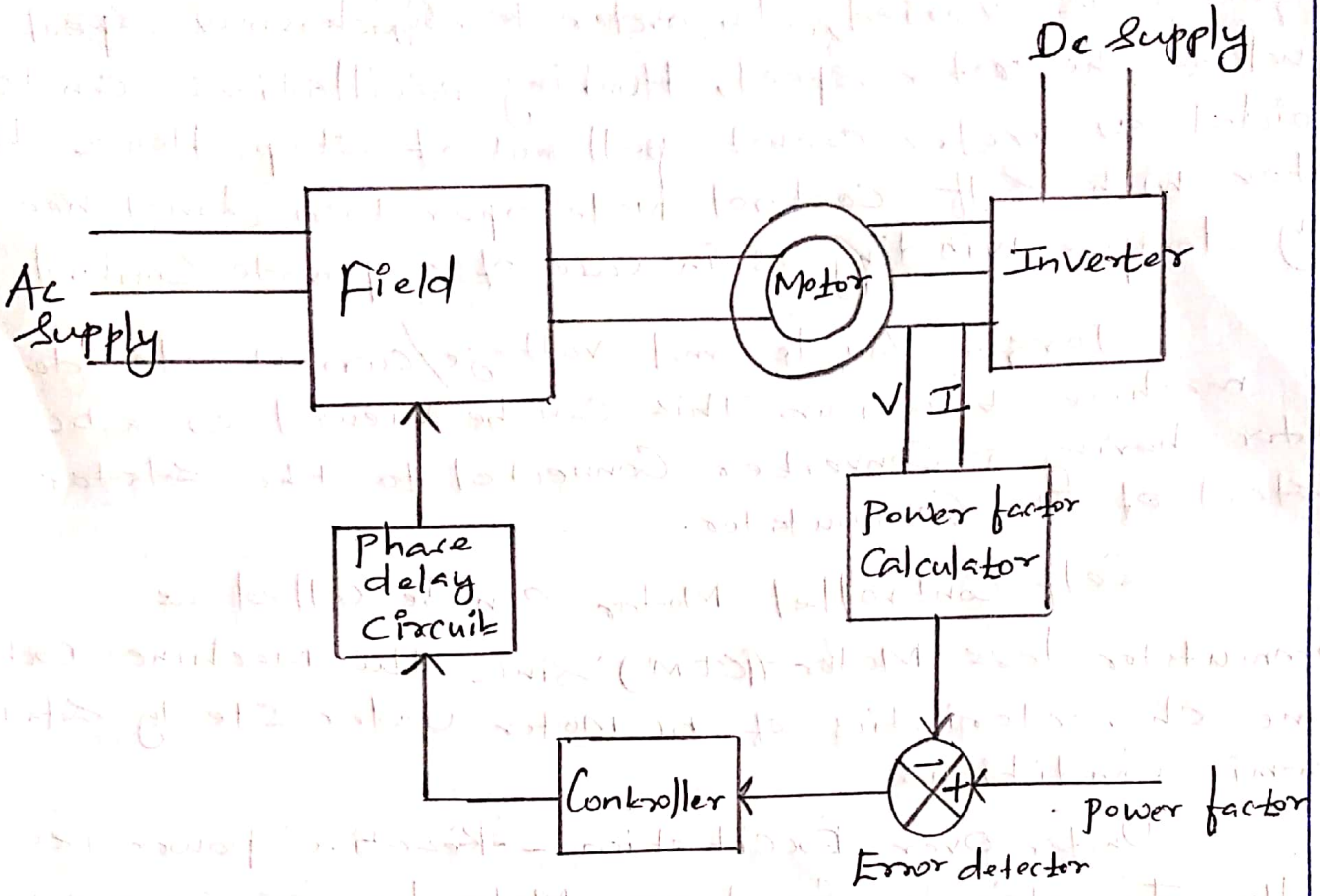
Under Over Excitation - Reactive power is supplied to the Inverter by Synchronous Motor for SCR Commutation process.

Firing Angles are Synchronised with machine voltages.

Inverter Frequency and Machine voltage frequency are equal and this type of Inverters called Load Commutated Inverter (LCI).

POWER FACTOR CONTROL:

(b)



Automatic closed loop Adjustment of power factor. The main Adjustment of PF is Variation of the field current (Its possible in Wound machine) If the motor is operated at the PF Unity, the Current drawn by it will have the lowest magnitude for given power Input and lower Copper losses, The motor voltage and current are sensed fed to PF calculator (PF Converts Phase Angle its Actual PF), This will Compared to Computed PF and error signal is fed Controller Varies the Field Current PF Confirmed to the Commanded value.

4. 3ϕ Voltage Source Inverter fed SM drive:

→ Synchronous motor drive can be controlled either by using self control mode and separate control mode

→ Self control mode posses good stability behaviour under steady state and dynamic conditions. (commutatorless DC Motor).

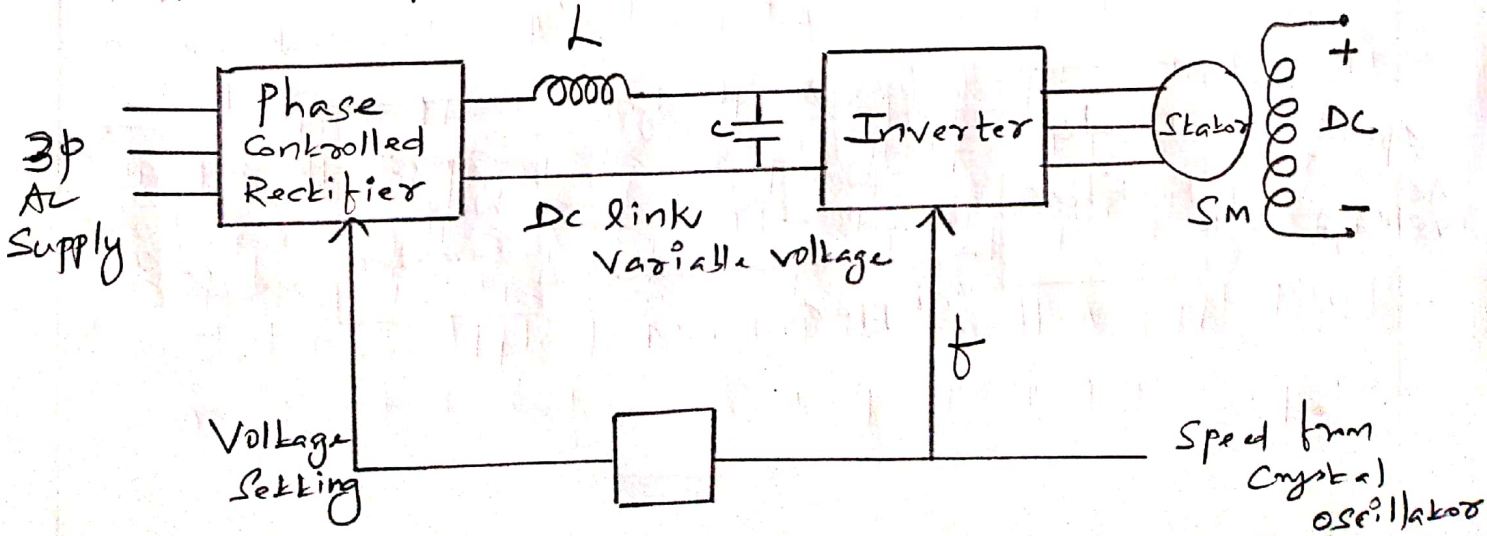
→ 180° Conduction mode cannot be achieved using LCI.

(i) Square wave Inverters
(ii) PWM Inverters
(iii) Chopper with Square wave Inverters

SWI → o/p waveform is square wave shape.
→ At very low speeds, Its tedious to achieve Commutation of Thyristors
→ This method suitable for medium to High speed Appl.

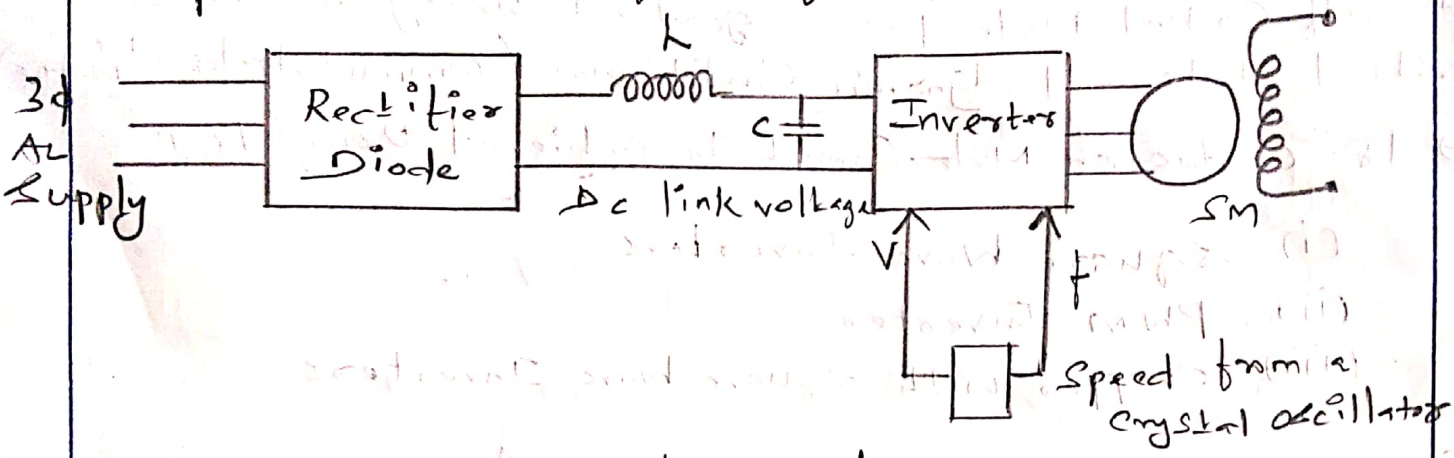
PWMI → PWM technique used in Inverter inorder to provide voltage control. within it
→ No difficulties in providing Commutation at very low speeds
→ Wide range of speed control is possible.

CSWI → DC link Inductnce is eliminated using chopper
Control of Synchronous Motor.
→ circuit is Complex
→ Non sinusoidal o/p voltage
→ Torque developed and machine losses can be found.

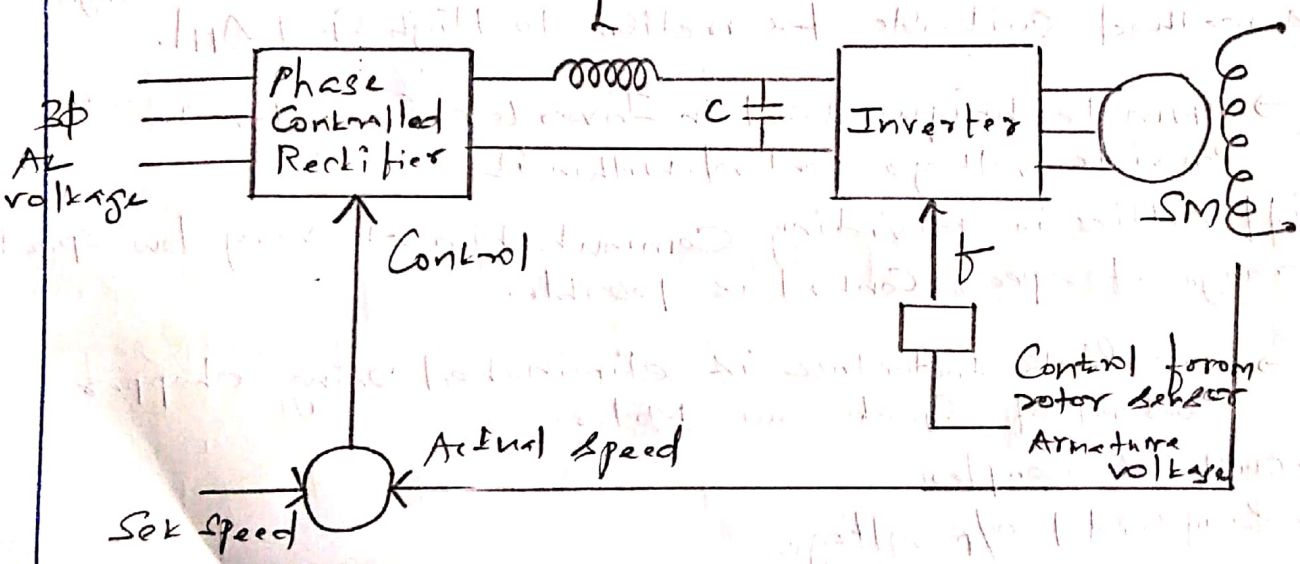


Possible Combinations of VSI fed SM:

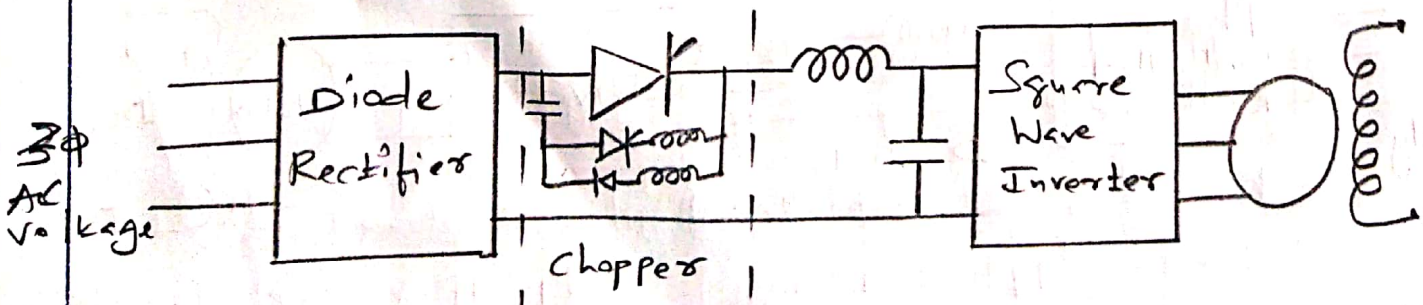
Separate Control of SM fed from Square Wave Inverter



Self Control of SM fed from Square Wave Inverter

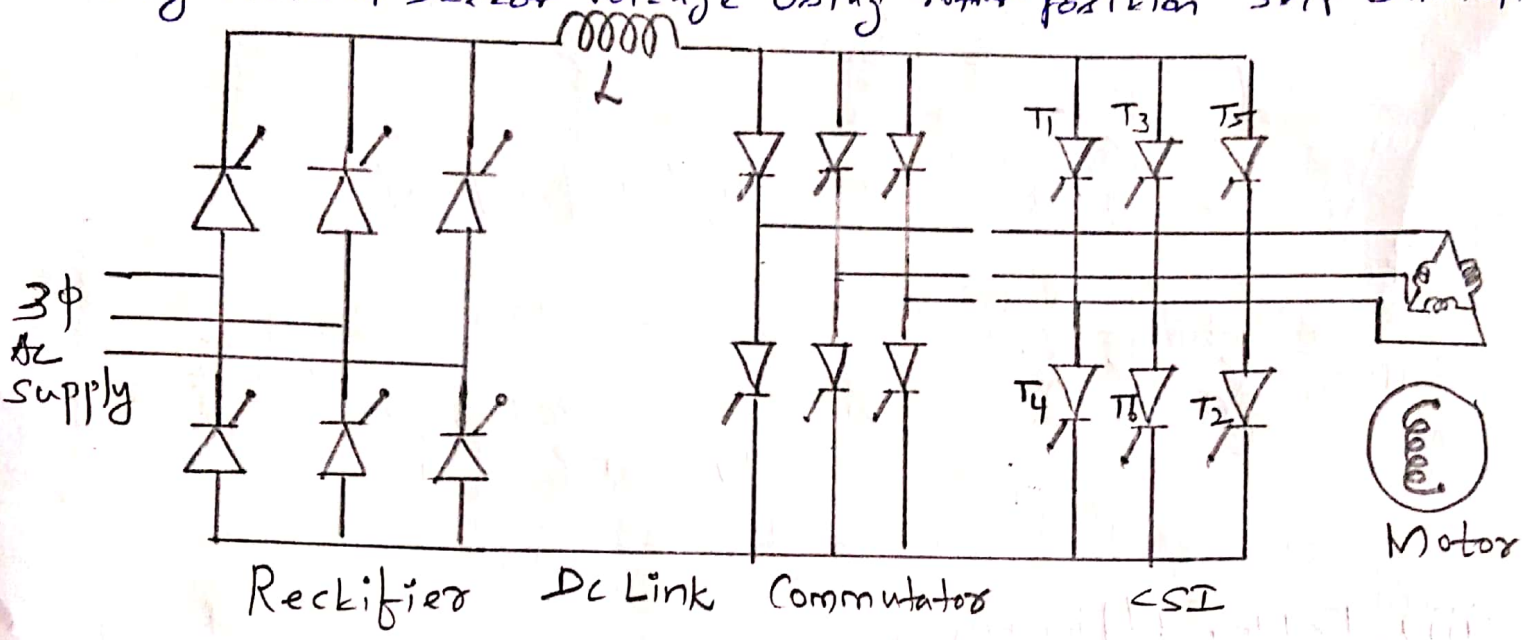


Fed from chopper with Square Wave Inverter



5. 3ϕ Current Source Inverter fed Synchronous Motor drive:

CSI fed Synchronous motor can be operated either in self control mode (or) Separate control mode. But self control mode is most preferable method & good stability sensing Induced Stator voltage using rotor position self control.



In stacking Commutation, there will be voltage spikes in the o/p voltage which cause damage to the Insulation, In order to avoid the spikes, damper windings are generally used in CSI fed Synchronous Motor drive.

Adv:

(i) Four Quadrant operation can be achieved without using Additional Converter.

(ii) Inherent Regeneration Capacity.

D. Adv:

(i) When Commutation is instantaneous, the motor current will have quasi Square wave shape.

(ii) Performance gets lowered due to Non sinusoidal Motor Current.

(iii) Due to Heat the presence of Harmonic Content in Stator current particularly at low speeds.

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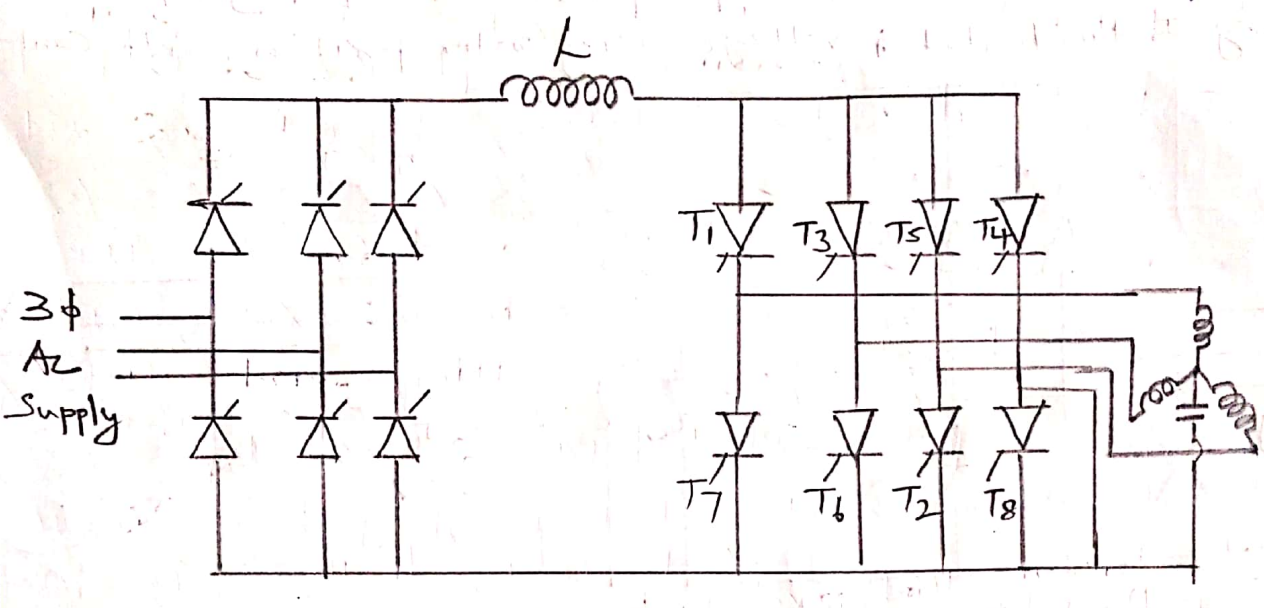
CSI with forced Commutation circuit:

DACE Cultivating Technology

Features:

(i) Inverter circuit cost becomes High

(ii) Extended range of speed operation (Zero to base speed)



(iii) Better Efficiency

(iv) Can be employed for low to medium power Appl (CLM Mode)

(v) Machine is being operated at Unity PF.

(vi) Since its Applicable for low speed operation, Size of forced Commutation circuit is very small.

(i) CSI with Individual Commutation (Auxillary thyristor provided with main thyristor)

(ii) Third Harmonic Commutated Auto Sequential CSI (ASCSI) [Commutation at low speeds b/w Star point and Common point of 2 Auxillary Thyristor) Commutating Capacitor is Inserted which mean Commutation low speeds.

(iii) Artificial Quenching:

Rotor position sensor and its Sends signal to Control Unit of load side Converter block gating pulses to the outgoing thyristor and to deliver gating pulse to the Incoming thyristor.