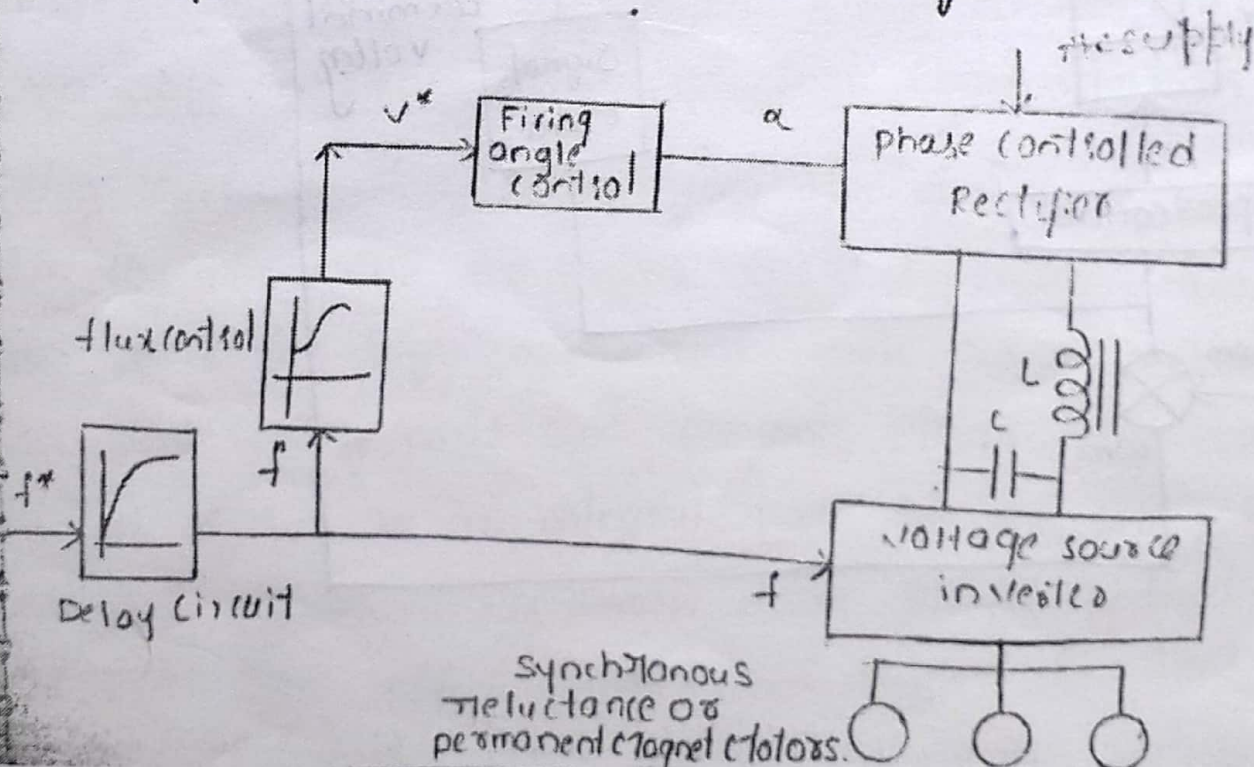


6 Control of Synchronous Motors

- Separate control or two Synchronous or open loop control method
- Self control or closed loop self control Synchronous method
- load commutated inverter fed Synchronous motor
- closed loop speed control of load commutated inverter fed Synchronous motor
- voltage source inverter fed Synchronous motor
- cyclo converter fed Synchronous motor drive.

Separate Control of synchronous motor (or) True Synchronous mode (or) open loop control method

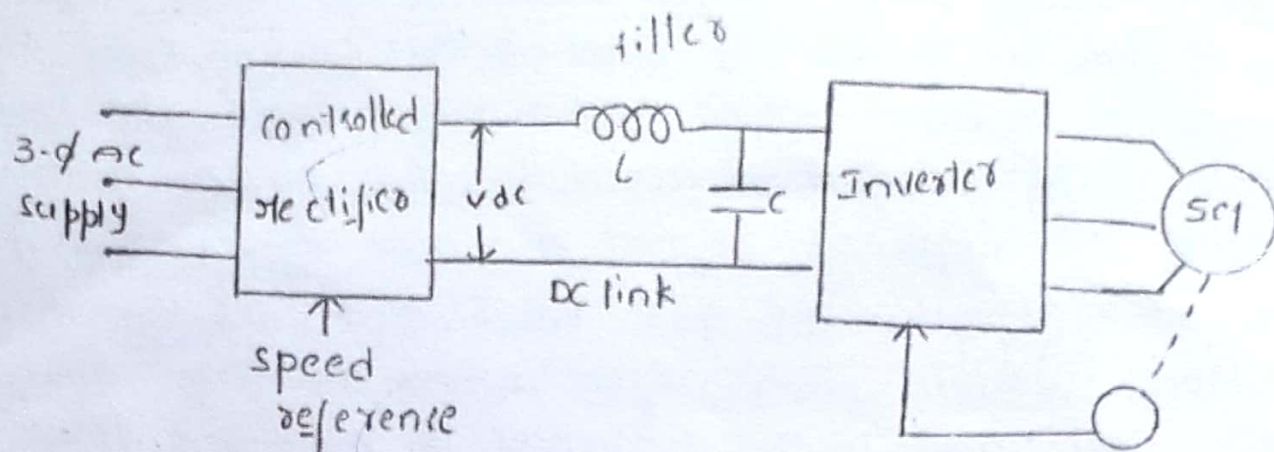
the inverter V/f ratio is kept constant to ensure that the motors operate at full flux at all speeds. this ensures constant torque capability. In this all machines are connected in parallel to the same inverter so that they move in synchronism corresponding to the command frequency f^* at the input. the command frequency passes through the delay circuit and the delay circuit output is applied to the voltage source inverter, so that the rotor speed is able to track the changes in frequency.



A flux control block changes stator voltage with frequency $\propto 1/f$ to maintain a constant flux below rated speed and a constant terminal voltage above rated speed. The speed can be varied from zero to the full value by gradually varying the frequency. Beyond the base speed, the dc link voltage saturates and machine enters the field weakening constant power region, where the torque decreases with an increase in the frequency. If prolonged low speed operation is required, improved cooling is needed, speed being obviously determined by the inverter frequency. Speed changes must be made slowly to avoid possibility of exceeding the pull-out torque angle which may result in loss of synchronism.

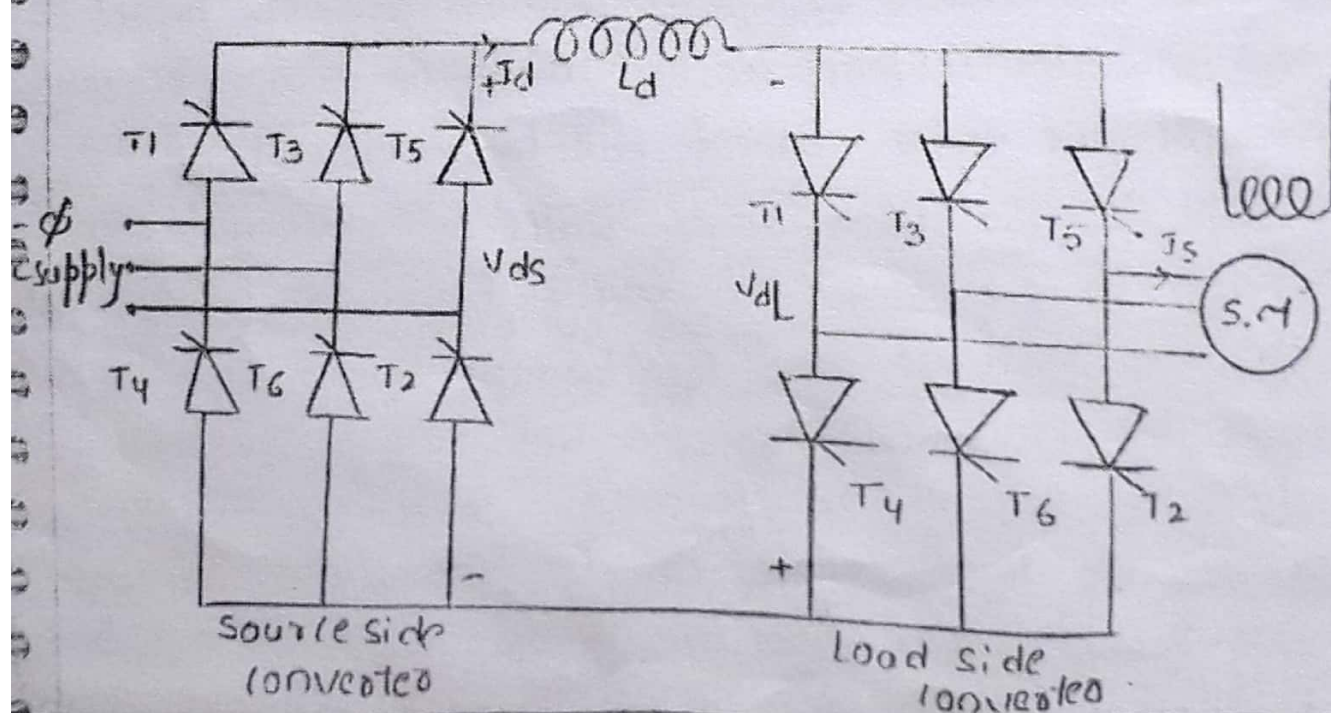
Closed Loop Self-Control of Synchronous Motor

By using closed loop self control of synchronous motor method, hunting of motor, problems of instability and poor dynamic behaviour can be eliminated. The inverter may be CSI or VSI depending on type of inverter the dc source may be controllable current source or controllable voltage source. If the dc input to the inverter is kept constant and the motor starts from rest, the motor current will be large at first but will decrease with speed until the motional emf generated in the stator is nearly equal to the applied voltage. The speed of the synchronous motor can be controlled by controlling the dc link voltage to the inverter. By varying the controlled rectifier firing angle, the dc link voltage can be controlled. At very low speeds, however, the generated emf is insufficient so the motor may be put in open loop control.



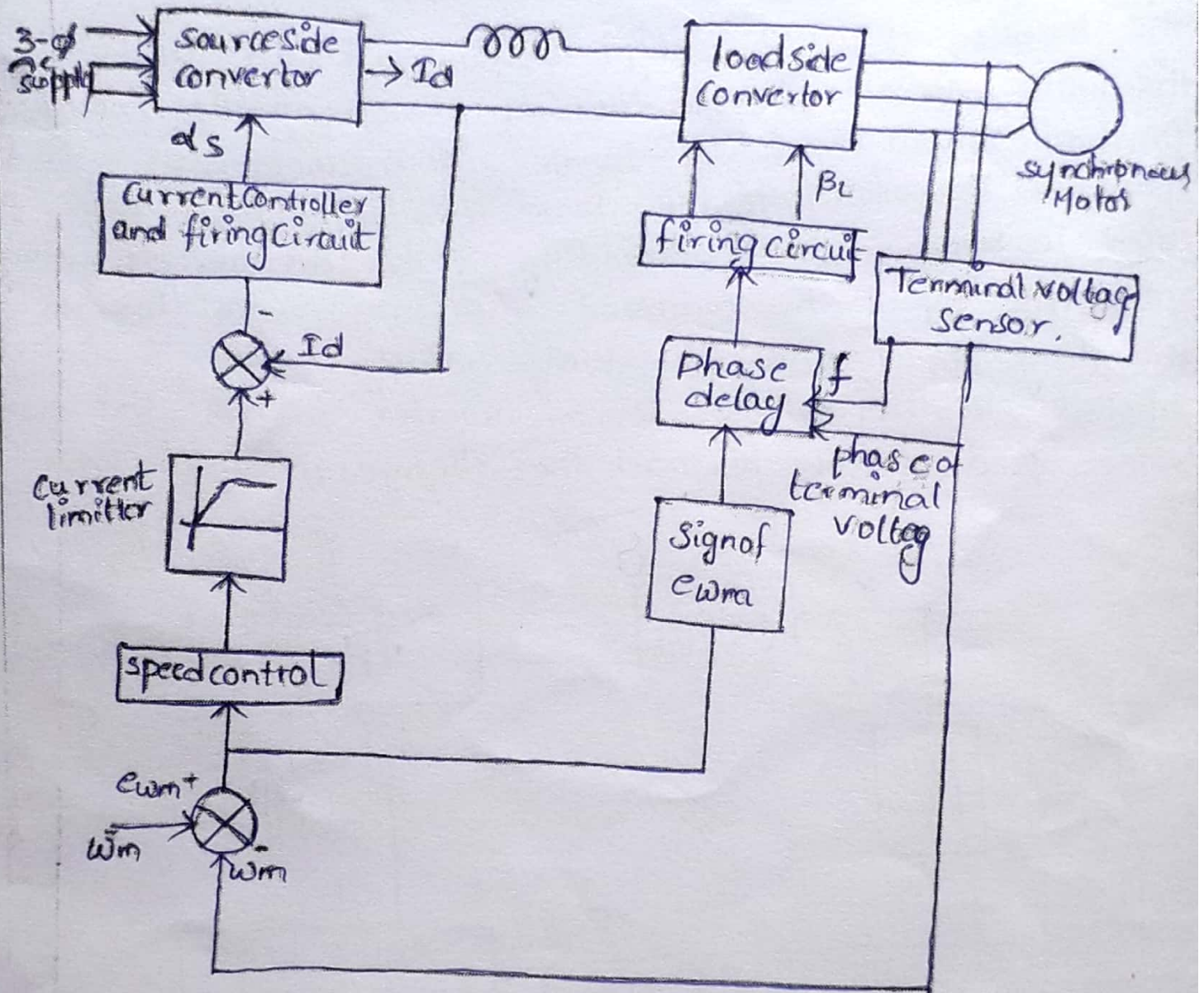
Load-Commutated inverter-fed Synchronous motor

In this scheme there are two converters, namely the Source side Converter and load side Converter. The Source side Converter is a six-pulse line commutated thyristor converter. For the firing angle range $0 \leq \alpha_s \leq 90$ the converter works as line-commutated fully controlled rectifier. By adjusting the field Excitation of Synchronous motor we can operate the Synchronous motor at leading power factor. In this condition the inverter operates as load commutated circuit, these circuits are also called self controlled circuits.



with $0 \leq \alpha_s \leq 90$, $90 \leq \alpha_r < 180$, the source side converter acts as a inverter power flow from ac source to the motor thus gives motoring operation when the firing angle changes such that $90 \leq \alpha_s < 180$ and $0 \leq \alpha_r \leq 90$ load side converter acts as a rectifier and the source side converter acts as an inverter power flow is reversed and machine operates in regenerative braking. Speed control can be made by controlling the line side converter firing angles.

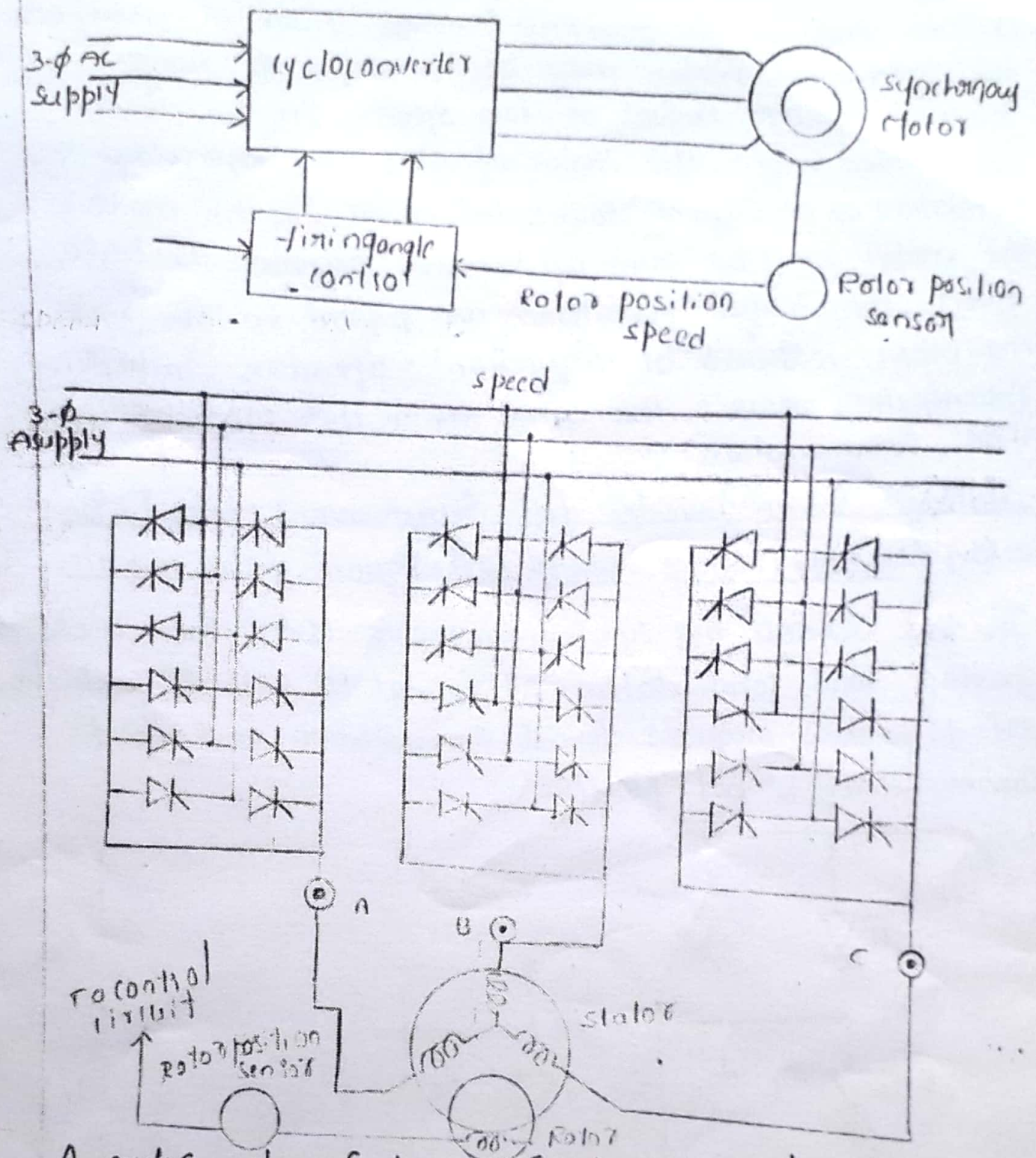
Closed loop Speed control load commutation inverter Synchronous motor drive



the phase controlled thyristor rectifier on the supply side of the dc link has a current regulating loop and operates a controlled current source the regulated dc current is delivered through the dc link inductor to the thyristor ICI which supplies square-wave line currents to the synchronous motor. the terminal voltage sensor generates reference pulse of the same frequency as the machine-induced voltages. the phase delay circuit shifts the reference pulses suitably to obtain control at a constant commutation lead angle. Depending on sign of speed error β can be set to provide motoring or braking operation the speed ω_m can be sensed either from the terminal voltage sensor or from a separate tachometer. An increase in reference speed ω_m produces a positive speed error, and β value set for motoring operation. the speed controller and current limiter set the dc link current reference at maximum permissible value. Similarly reduction in reference speed produces a negative speed error which leads to set β for braking operation.

Cycloconverter fed Synchronous motor drive or Variable frequency drive or line commutation

When cycloconverter is employed the drive is fed directly from the ac mains. these types of drives are used for high applications such as compressors fan steel rolling mills and cement plants. the rotor position sensor is an integral part of the self-controlled synchronous motor drive. Electro-optical sensors, Hall effect sensors and digital encoders are most commonly used devices. where this motor is used.



A cycloconverter feeding a Synchronous motor can be

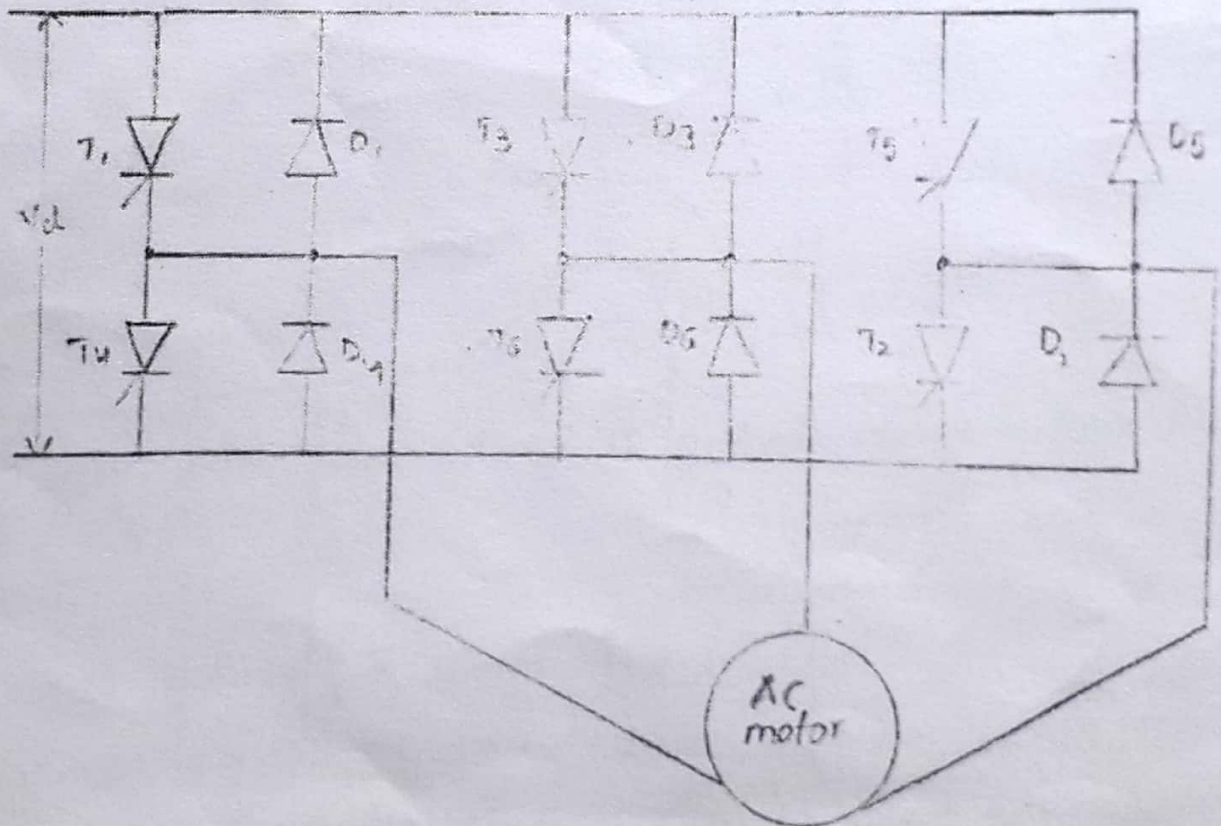
- 1 line-commutated
- 2 load commutated.

In the line-commutated mode it provides a variable-frequency variable voltage source to the motor. the motor is in self-controlled mode.

the converter receives its firing pulse from a rotor position sensor or an armature voltage sensor. A cycloconverter fed synchronous motor may be employed for large power reversible drives at low speeds. In the load-commutated mode, the motor operates on trapezoidal excitation as a current source fed motor. In this mode, the motor may be run up to and beyond its base speed. The torque pulsations are present in this mode. The other features of 4-quadrant operation, including power factor, remain the same as in the case of the line commutation.

Voltage Source Inverter fed Synchronous motor Drive (or) Variable voltage inverter (or) Square wave inverter

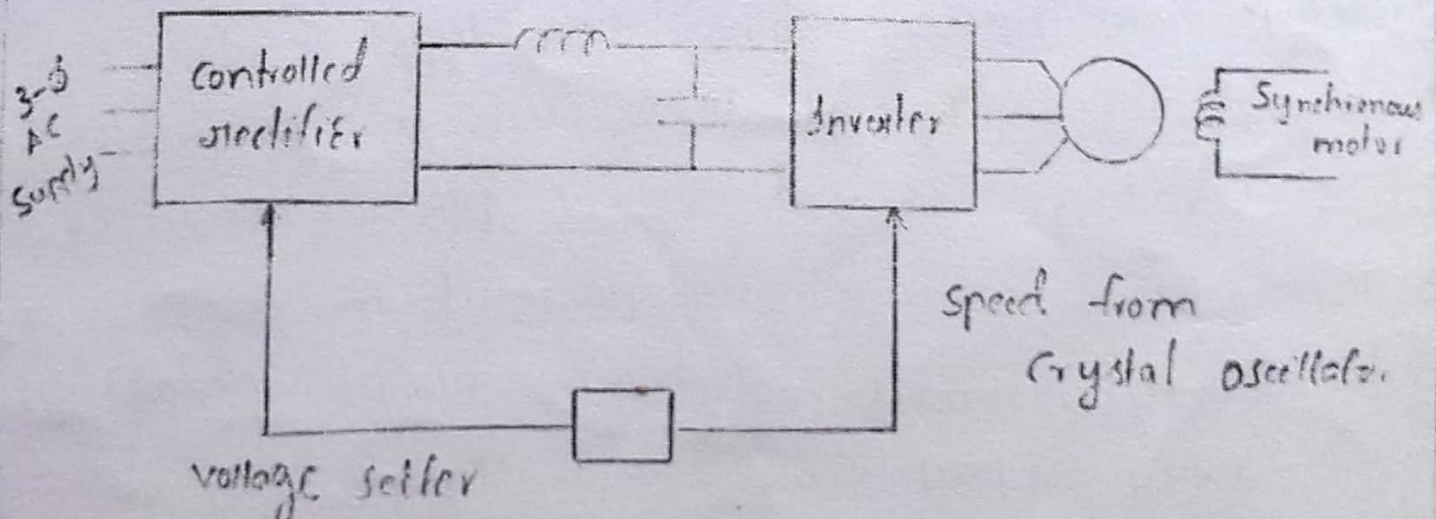
In this scheme the synchronous motor is fed from a CSI having load commutation. A normal VSI with 180° conduction of thyristors requires forced commutation and load commutation is not possible.



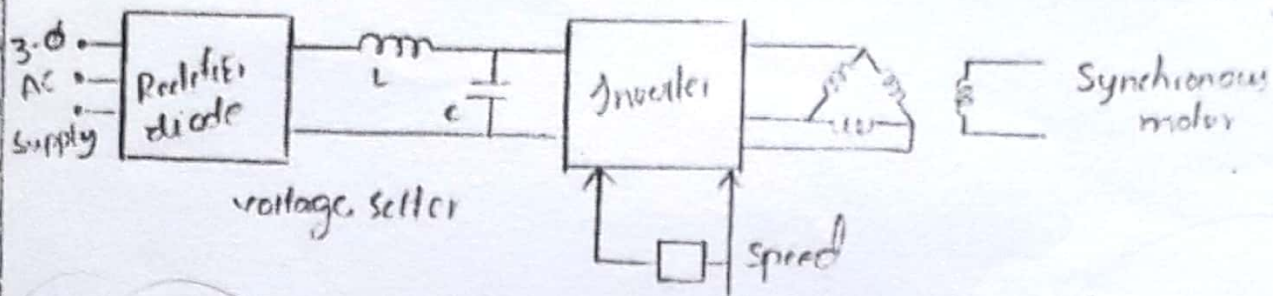
When a PWM inverter is used, the inverter voltage is controlled within the inverter itself, PWM Control is used and harmonic effects are reduced. When a PWM inverter is used two cases may arise, the inverter may be fed from a constant dc source, in this case regeneration is straightforward, the dc supply to the inverter may also be obtained from a diode rectifier. In this case, an additional controlled converter is required on the line side.

A Square wave inverter drive must have a phase controlled converter on the line side. Due to phase control the line power factor is very poor. A diode rectifier is sufficient in the case of PWM inverter. The line pf improves to unity. A PWM drive has a better dynamic response than a square wave drive. This finds application as a general purpose industrial drive for low and medium power application.

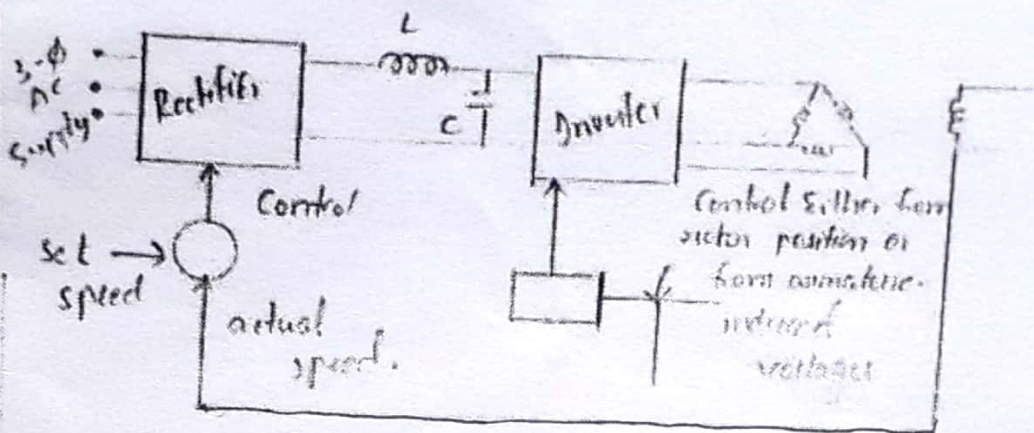
Separate control of synchronous motor fed from square wave inverter



Separate Control of synchronous motor fed from PWM inverter



Self Control of Synchronous motor fed from Square wave Inverter



Self Control of synchronous motor fed from PWM inverter

