

Slip Power Recovery Scheme(contd..)

AC Equivalent Circuit of Static Kramer Drive(cont'd)

The resulting air gap power is given by:

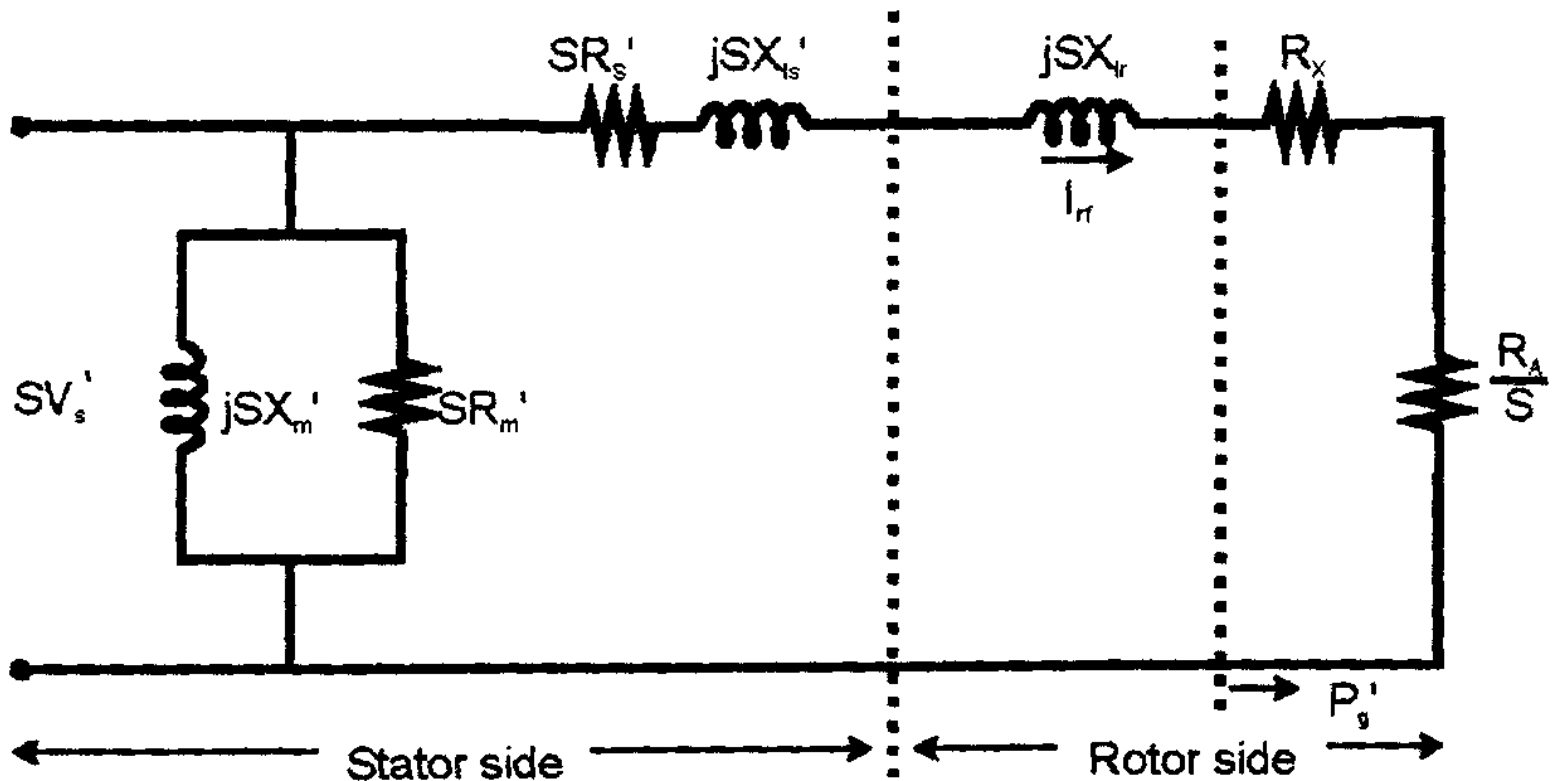
$$P'_g = I_{rf}^2 R_X + I_{rf}^2 \frac{R_A}{S}$$

where: $R_X = \left(\frac{\pi^2}{9} - 1 \right) (R_r + 0.5R_d)$

and $R_A = (R_r + 0.5R_d) + \frac{\pi}{3\sqrt{6}} \frac{1.35V_L}{n_2 I_d} |\cos \alpha|$

AC Equivalent Circuit of Static Kramer Drive(cont'd)

The per-phase equivalent circuit derived from these equations (referred to the rotor) is shown below:



Torque Expression

The average torque developed by the motor = total
fundamental air gap power

synchronous speed of motor

$$\therefore T_e = 3 \left(\frac{P}{2} \right) \frac{P'_{gf}}{\omega_e} = 3 \left(\frac{P}{2} \right) \left(\frac{I_{rf}^2 R_A}{s} \right)$$

where P'_{gf} = fundamental frequency per-phase air
gap power.

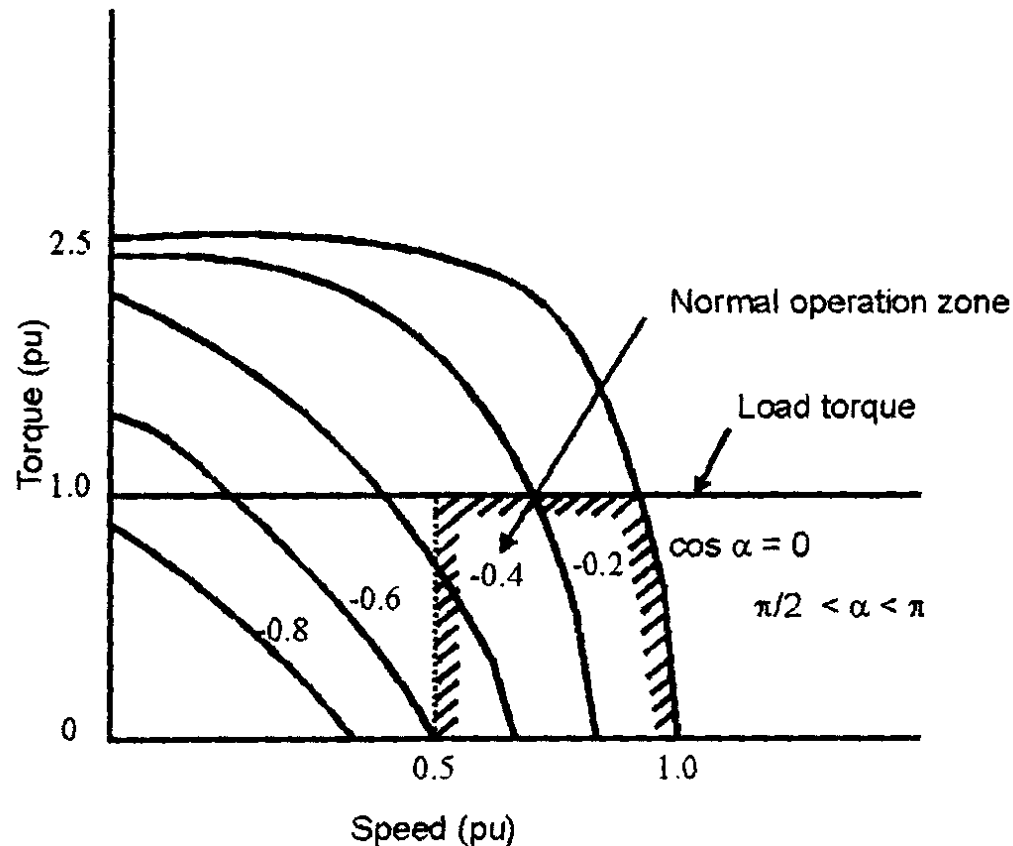
Torque Expression (cont'd)

A torque expression in terms of inverter firing angle may be derived (see text pg. 320) resulting in:

$$T_e \approx 3 \left(\frac{P}{2} \right) \frac{V_s^2}{\omega_e R_r} \left[\frac{|\cos \alpha|}{sn_2} \left(\frac{s^2}{n_1} - \frac{|\cos \alpha|}{n_2} \right) + s \left(\frac{s}{n_1} - \frac{|\cos \alpha|}{sn_2} \right)^2 \right]$$

Torque Expression (cont'd)

The torque-speed curves at different firing angles of the inverter are shown below:

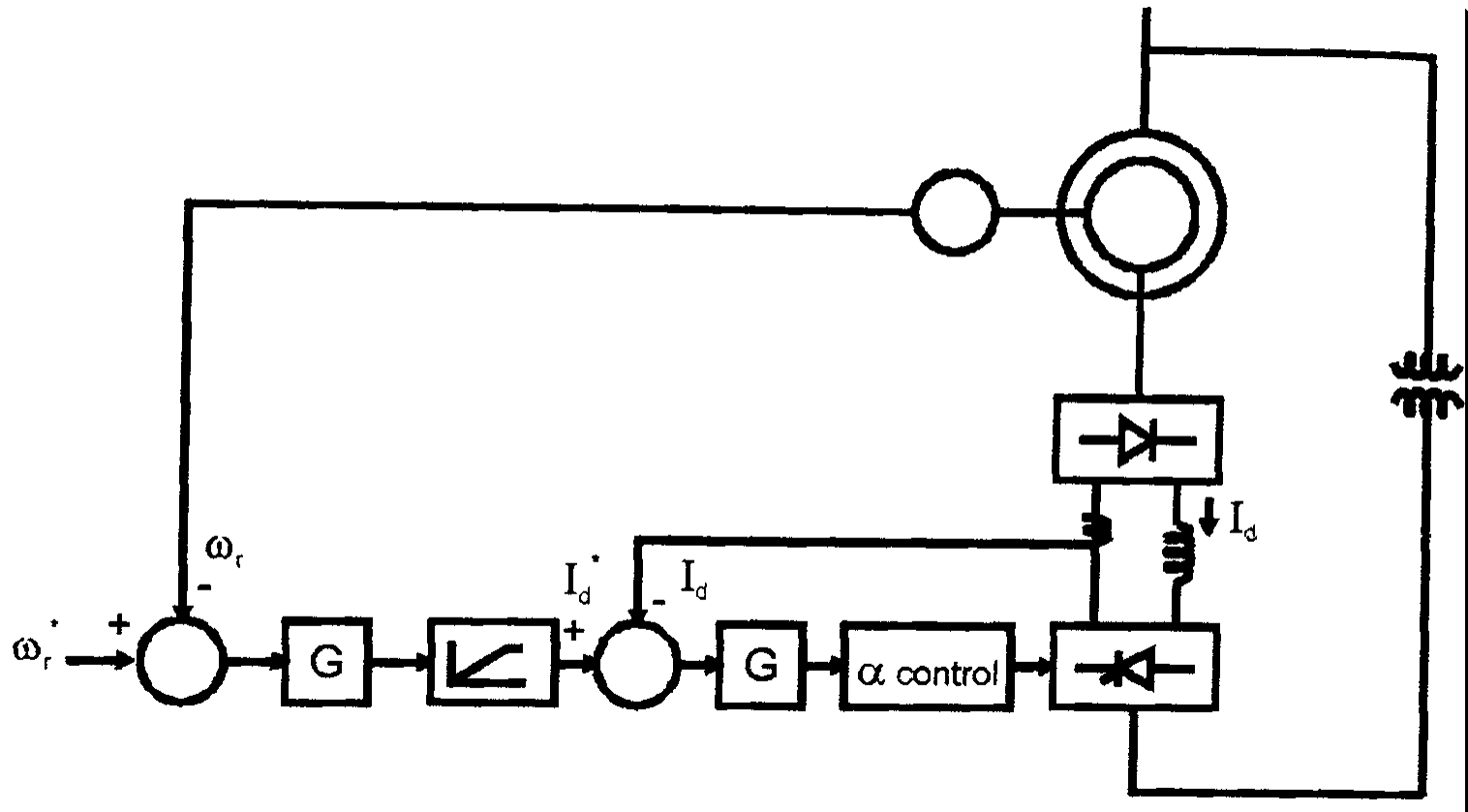


Harmonics in a Static Kramer Drive

The rectification of slip-power causes harmonic currents in the rotor which are reflected back into the stator. This results in increased machine losses. The harmonic torque is small compared to average torque and can generally be neglected in practice.

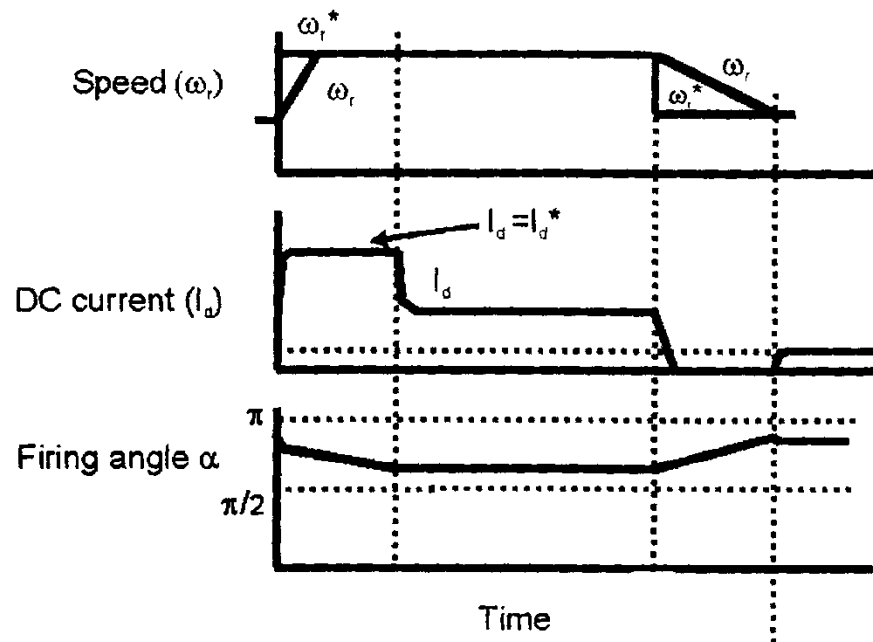
Speed Control of a Static Kramer Drive

A speed control system for a static Kramer drive is shown below:



Speed Control of a Static Kramer Drive (cont'd)

The air gap flux is constant and the torque is controlled by the dc link current I_d (controlled in the inner control loop). The speed is controlled via the outer control loop (see performance curves below).



Power Factor Improvement

As indicated earlier, the static Kramer drive is characterized by poor line PF because of phase controlled inverter.

One scheme to improve PF is the commutator-less Kramer drive - see Bose text pp. 322-324 for description.

Static Scherbius Drive

The static Scherbius drive overcomes the forward motoring only limitation of the static Kramer drive.

Regenerative mode operation requires the slip power in the rotor to flow in the reverse direction. This can be achieved by replacing the diode bridge rectifier with a thyristor bridge. This is the basic topology change for the static Scherbius drive from the static Kramer drive.

Static Scherbius Drive (cont'd)

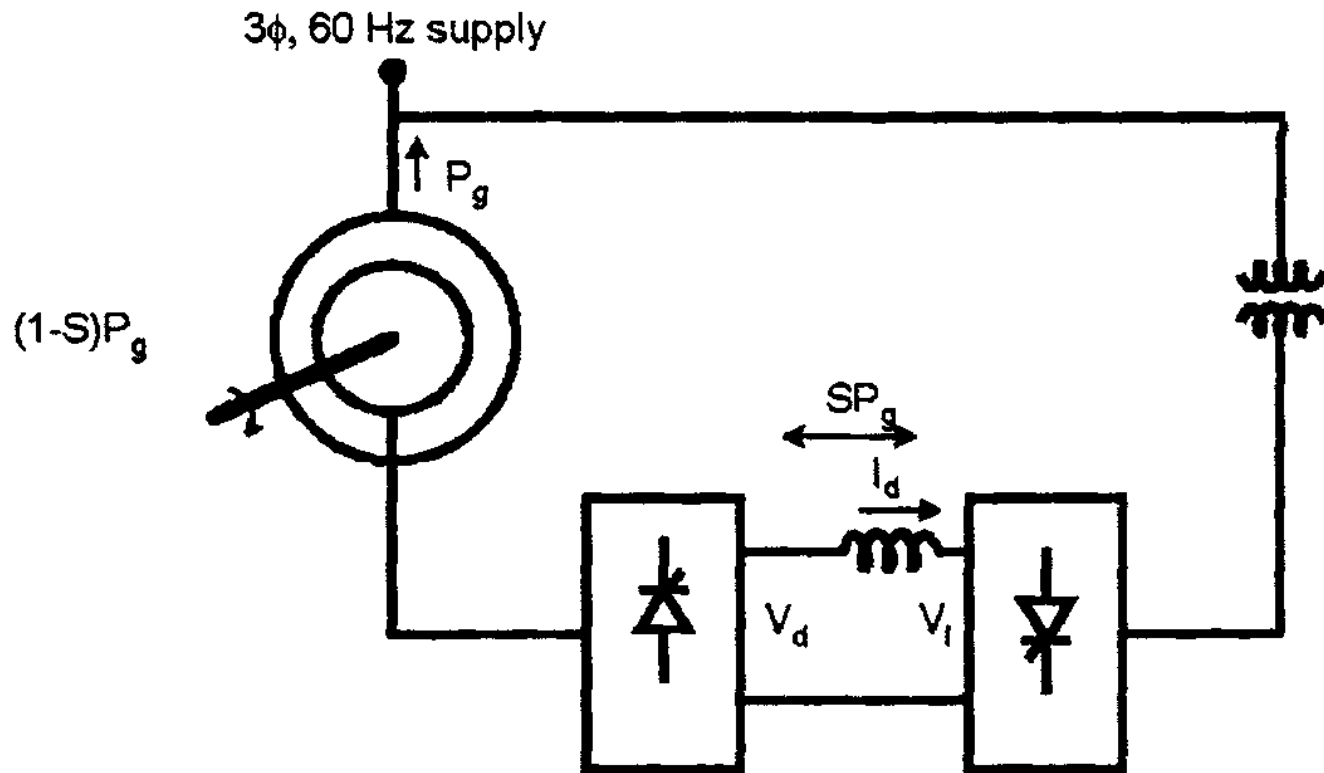


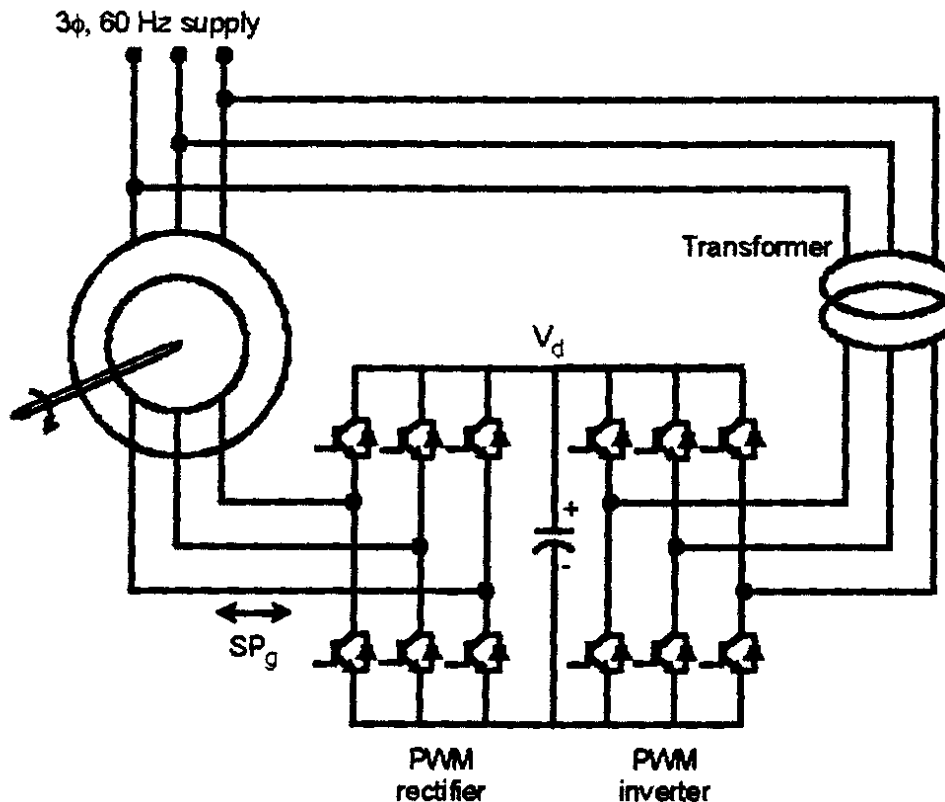
Figure 7.18 Static Scherbius drive system using dc-link thyristor converters

Static Scherbius Drive (cont'd)

One of the limitations of the previous topology is that line commutation of the machine-side converter becomes difficult near synchronous speed because of excessive commutation angle overlap. A line commutated cycloconverter can overcome this limitation but adds substantial cost and complexity to the drive.

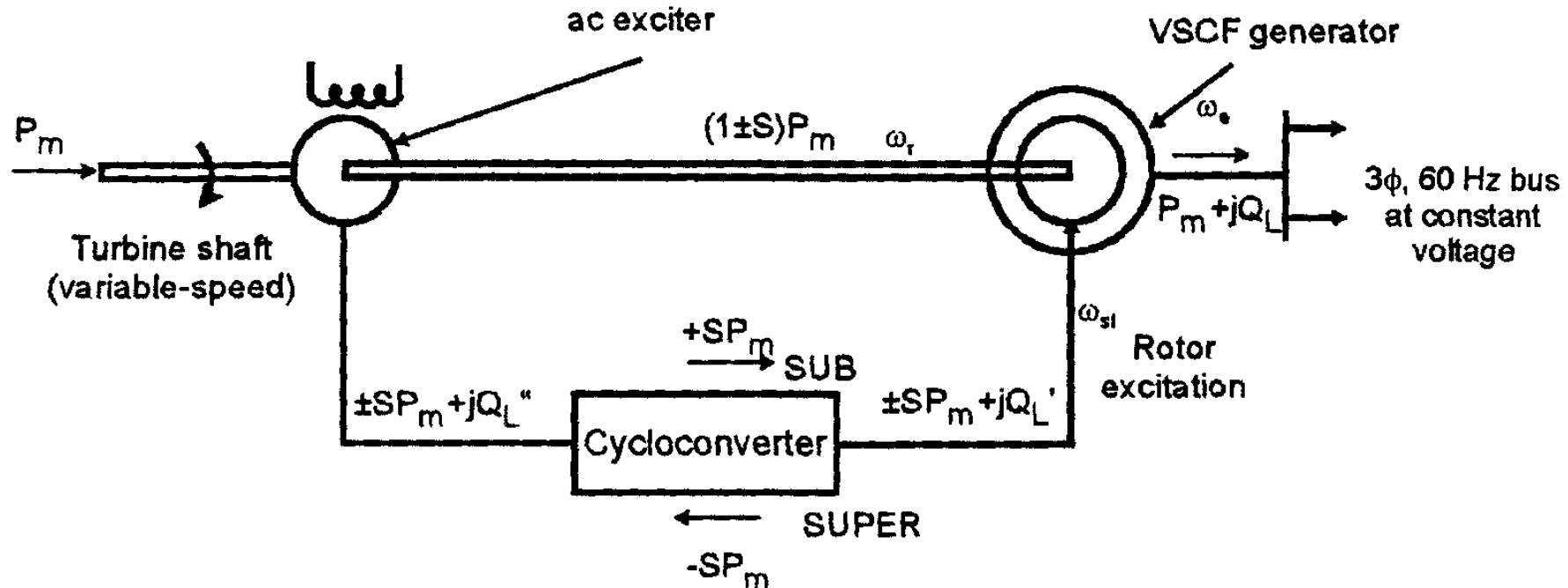
Static Scherbius Drive (cont'd)

Another approach is to use a double-sided PWM voltage-fed converter system as shown below:



Modified Scherbius Drive for Shipboard VSCF Power Generation

Another approach that has been used for stand-alone shipboard power generation is shown below:



Modified Scherbius Drive for Ship-board VSCF Power Generation (cont'd)

In this approach an induction generator provides real stator power P_m to a 3Φ 60Hz constant voltage bus which is equal to the turbine shaft power and the slip power fed to the rotor by a cycloconverter. The stator reactive power Q_L is reflected to the rotor as sQ_L which adds to the machine magnetizing power requirement to give the total reactive power Q_L' of the cycloconverter. This power is further increased to Q_L'' at the cycloconverter input by the shaft-mounted synchronous exciter.

Modified Scherbius Drive for Ship-board VSCF Power Generation (cont'd)

The slip frequency and its phase sequence are adjusted for varying shaft speed so that the resultant air gap flux rotates at synchronous speed.

At **subsynchronous speeds** the slip power sP_m is supplied to the rotor by the exciter and so the remaining output power $(1-s)P_m$ is supplied to the shaft. At **supersynchronous speeds**, the rotor output power flows in the opposite direction so that the total shaft power increases to $(1+s)P_m$.

Modified Scherbius Drive for Ship-board VSCF Power Generation (cont'd)

Rotor voltage and frequency vary linearly with deviation from synchronous speed. For example, if the shaft speed varies in the range of 800-1600 rpm with 1200 rpm as the synchronous speed ($s=\pm 0.33$) the range of slip frequency will be 0- \rightarrow 20Hz for a 60Hz supply frequency.