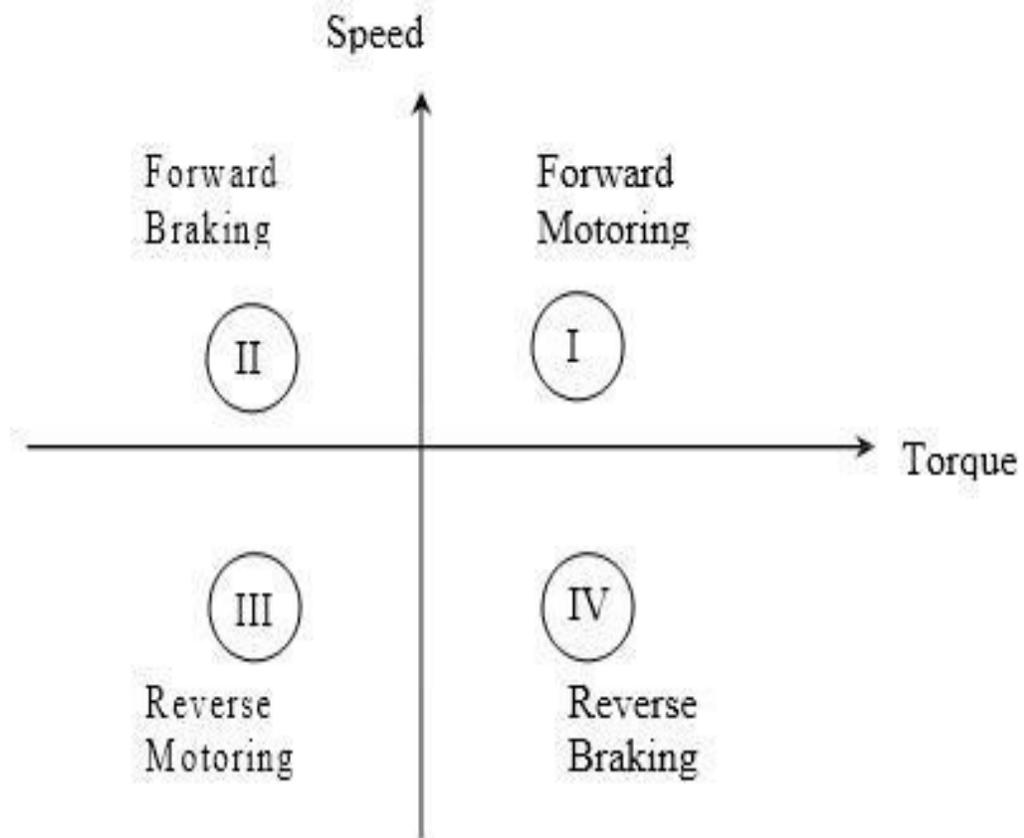


## 2.5 Four Quadrant Operation of a Converters:

### First Quadrant–Forward motoring mode

For first quadrant operation, thyristor S4 is kept on, thyristor S3 is kept off and thyristor switch S1 is operated. With S1, S4 ON, armature voltage  $V_a = V_s$  and armature current  $I_a$  begins flow. Here both  $V_a$  and  $I_a$  are positive giving first quadrant operation, when S1 is turned off, positive current freewheels through S4, D2. In this manner,  $V_a$ ,  $I_a$  can be controlled in this first quadrant, and operation gives forward motoring mode.



**Figure 2.5.1 Four quadrant operation of drives**

(Source: "Fundamentals of Electrical Drives" by G.K.Dubey, page-12)

### Second Quadrant–Forward braking mode

Here thyristor S<sub>2</sub> is operated and S<sub>1</sub>, S<sub>3</sub> and S<sub>4</sub> are kept off. With S<sub>4</sub> on, reverse or negative current flows through L<sub>a</sub>, S<sub>2</sub>, D<sub>4</sub> and E<sub>b</sub>. During the operation time of S<sub>2</sub>, the armature inductance 'L<sub>a</sub>' stores energy during the time S<sub>2</sub> is on. When S<sub>2</sub> is turned off, current is fed back to source through diodes D<sub>1</sub>, D<sub>4</sub>. Note that here  $(E + L(di/dt))$  is more than the source voltage V<sub>S</sub>. As the V<sub>S</sub> is positive and I<sub>a</sub> is negative, it is a second quadrant operation gives forward braking mode. In that power is fed back from armature to source.

### Third Quadrant–Reverse motoring mode

For third quadrant operation, thyristor S<sub>1</sub> is kept off, S<sub>2</sub> is kept on and S<sub>3</sub> is operated, polarity of armature back emf E<sub>b</sub> must be reversed for this quadrant operation. With thyristor S<sub>3</sub> is on, armature gets connected to source V. so that both V<sub>a</sub>, I<sub>a</sub> are negative, leading to third quadrant operation. When S<sub>3</sub> is turned off, negative current free wheels through S<sub>2</sub>, D<sub>4</sub>. In this manner only V<sub>a</sub> and I<sub>a</sub> can be controlled in the third quadrant.

### Fourth Quadrant–Reverse Braking mode

Here thyristor S<sub>4</sub> is operated and other devices kept off, back emf E<sub>b</sub> must have its polarity reversed as in third quadrant operation. With S<sub>4</sub> on, positive current flows through S<sub>4</sub>, D<sub>2</sub>, L<sub>a</sub> and E<sub>b</sub> (armature). Armature inductance L<sub>a</sub> stores energy during the time S<sub>4</sub> is on. When S<sub>4</sub> is turned off, current is fed back to source through diodes D<sub>2</sub>, D<sub>3</sub>. Here armature voltage V<sub>a</sub> is negative, but I<sub>a</sub> is positive, leading to the chopper drive operation in the fourth quadrant. Also power is fed back from armature to source.