Power electronics lab

Single phase Semi controlled rectifier

Eng :Eman Abu Hany

The Semi-controlled Double –pluse Bridge circuit B2H

Asymmetrical Semi-controlled Bridge circuit B2HZ

Symmetrical Semi-controlled Bridge circuit B2HC

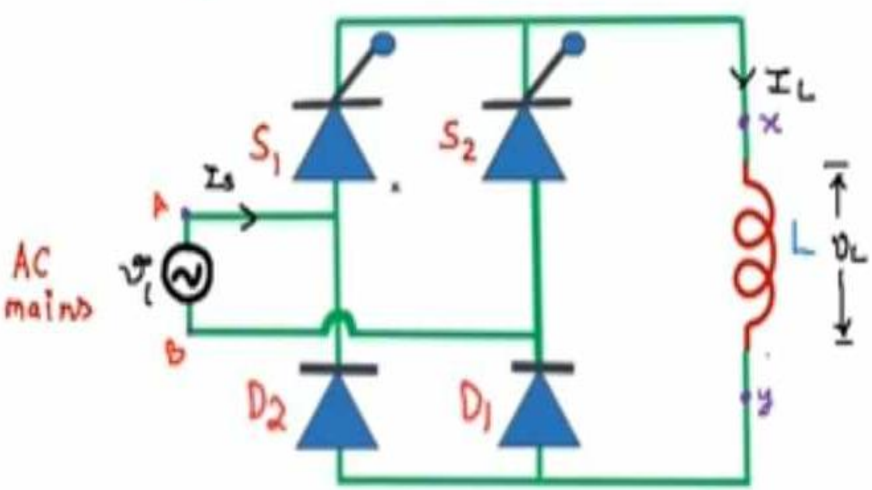
Semi Converter/Half Controlled Converter

- This configuration consists of combination of SCRs and diodes and used to eliminate any negative voltage occurrence at load terminals
- It is a single phase full wave converter.
- It has only one polarity of output voltage and current.
- It is also a first quadrant converter.
- In this circuit two diodes and two SCRs are connected in bridge configuration
- Free wheeling takes place when operated with inductive loads.

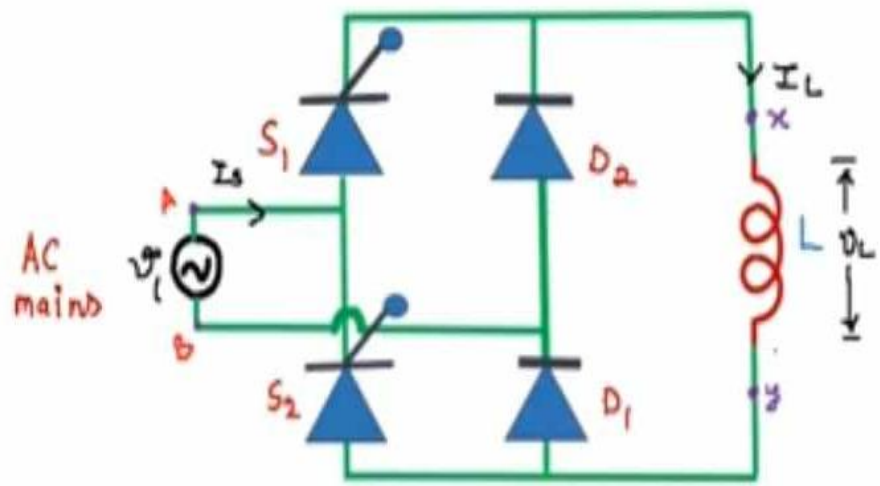
Semi Converter/Half Controlled Converter

Configuration of Semi Converter

Symmetrical Configuration



A-symmetrical Configuration



Semi Converter/Half Controlled Converter(with Resistive Load)

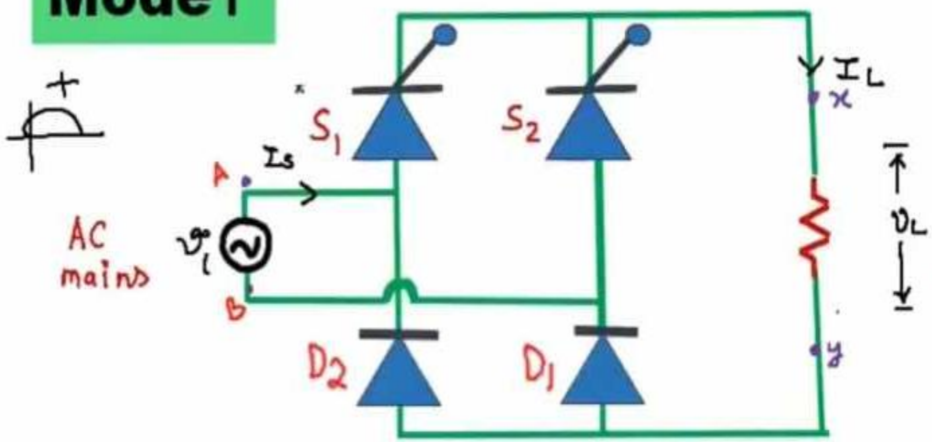
Operating Modes

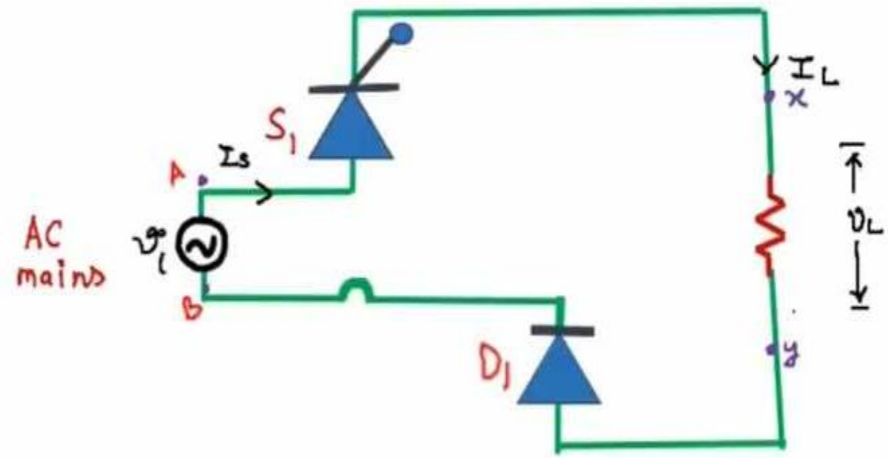
- **Mode I**: $\alpha \leq \omega t \leq \pi$
- **Mode II**: $\pi \leq \omega t \leq \pi + \alpha$
- **Mode III**: $\pi + \alpha \leq \omega t \leq 2\pi$
- **Mode IV**: $2\pi \leq \omega t \leq 2\pi + \alpha$

Resistive Load cannot store any energy in it , therefore free wheeling doesn't take place in semi converter with resistive Load

Semi Converter/Half Controlled Converter(with Resistive Load)

Mode I



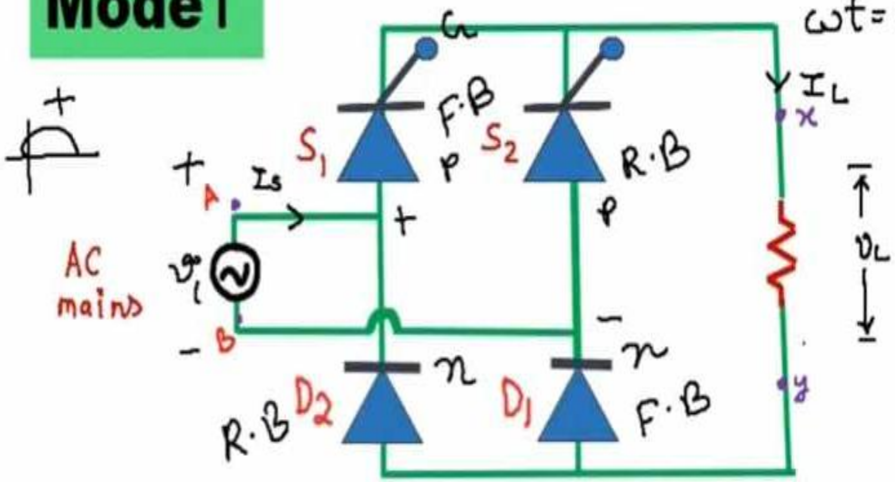


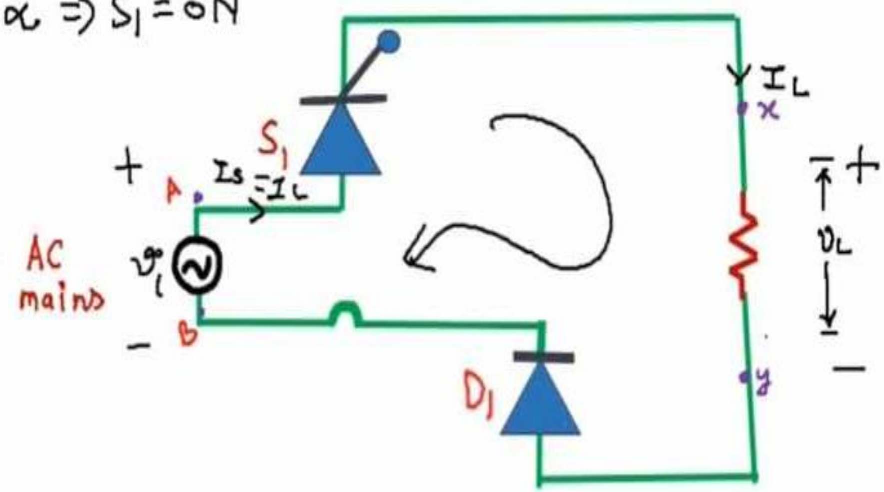
S1	S2	D1	D2	Is	VL

Semi Converter/Half Controlled Converter(with Resistive Load)

Mode I

$\omega t = \alpha \Rightarrow S_1 = ON$

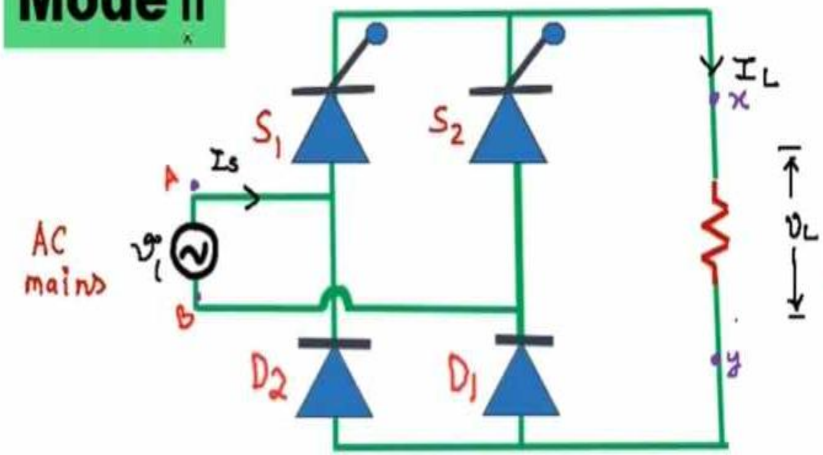


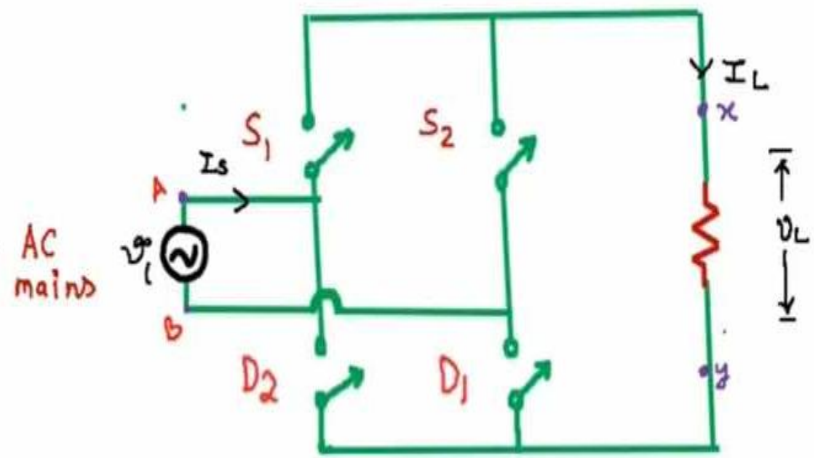


S_1	S_2	D_1	D_2	I_s	V_L
ON	OFF	ON	OFF	I_L	V_i
$I_{SCR_1} = I_L$	$I_{SCR_2} = 0$	$I_{d_1} = I_L$	$I_{d_2} = 0$		
$V_{SCR_1} = 0$	$V_{SCR_2} = V_i$	$V_{d_1} = 0$	V_{d_2}		

Semi Converter/Half Controlled Converter(with Resistive Load)

Mode II

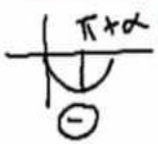


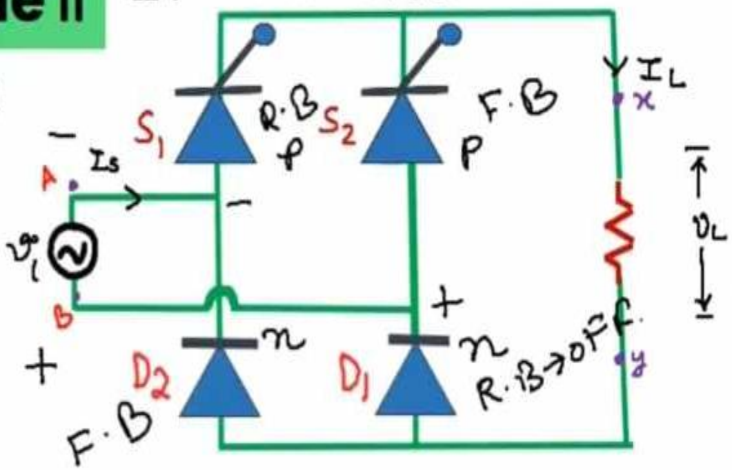


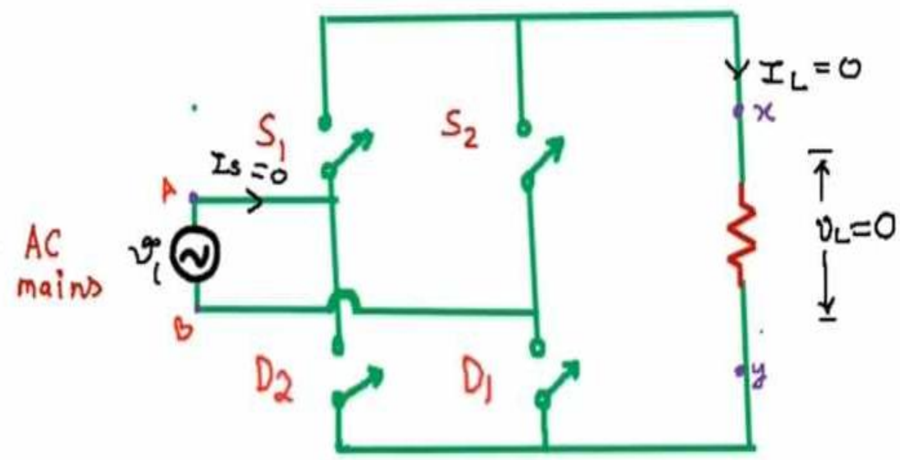
S_1	S_2	D_1	D_2	I_s	V_L

Semi Converter/Half Controlled Converter(with Resistive Load)

Mode II $\omega t = \pi$ to $\pi + \alpha$



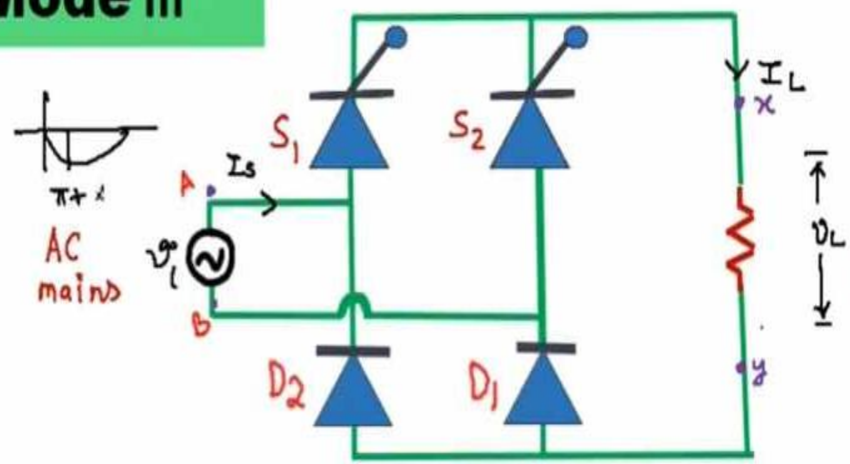


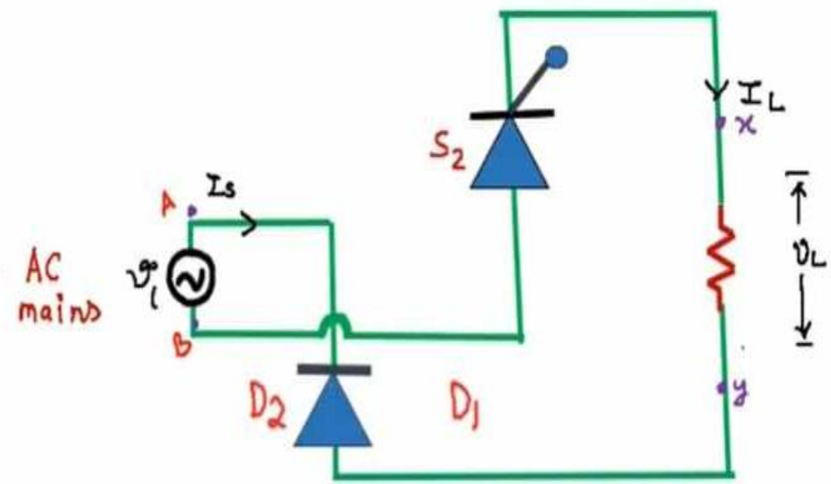


S1	S2	D1	D2	Is	VL
I=0	I=0	I=0	I=0	Is=0	VL=0

Semi Converter/Half Controlled Converter(with Resistive Load)

Mode III

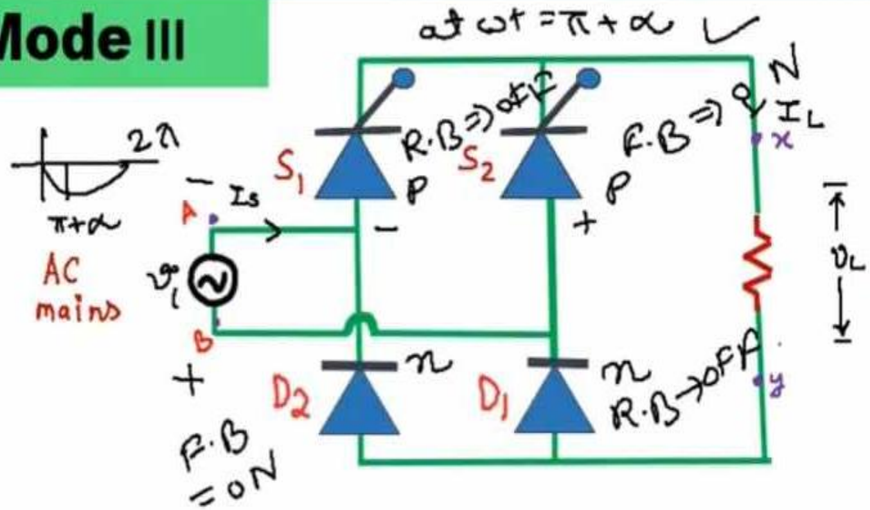


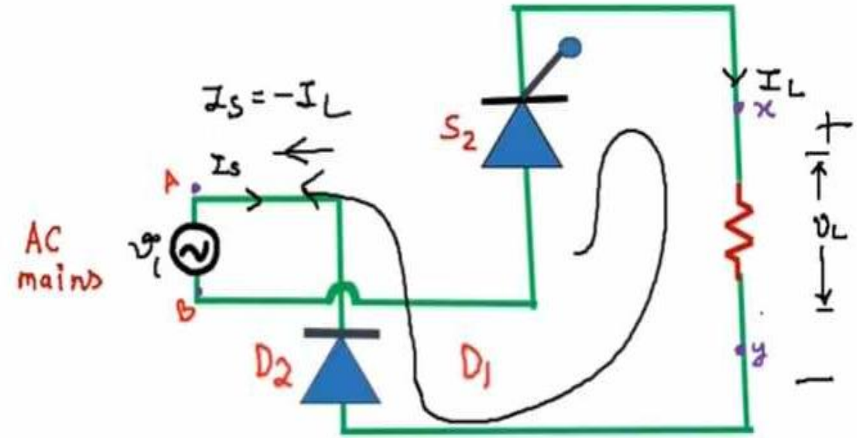


S_1	S_2	D_1	D_2	I_s	V_L

Semi Converter/Half Controlled Converter(with Resistive Load)

Mode III

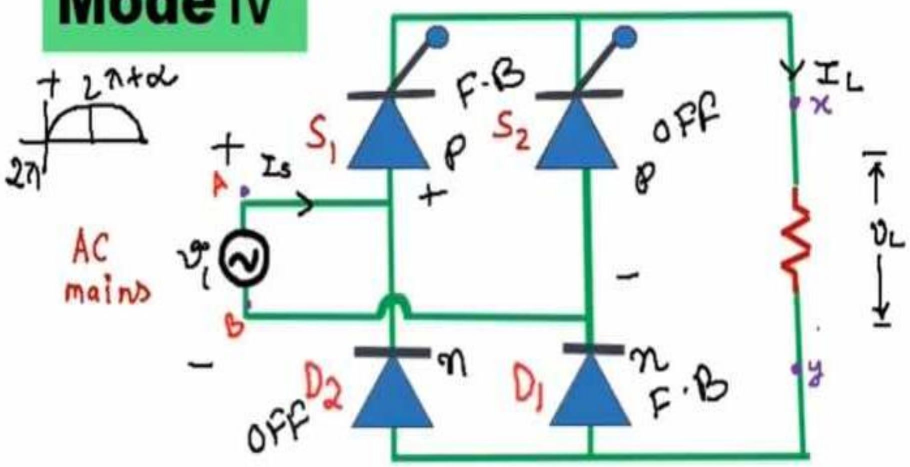


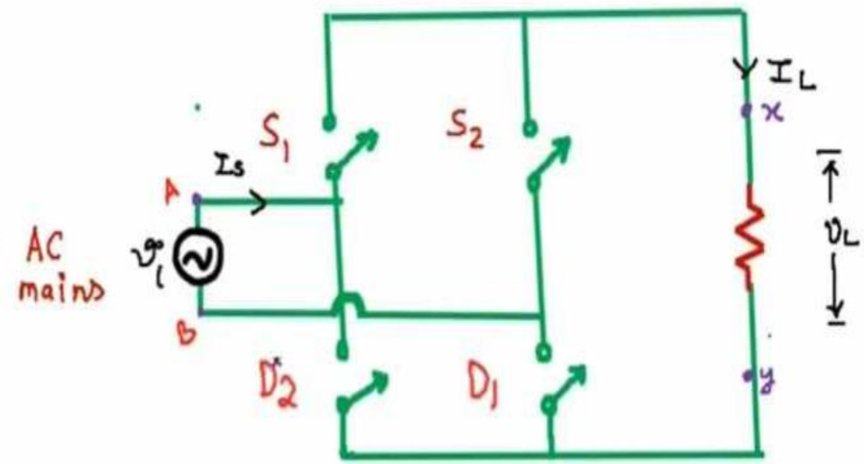


S_1	S_2	D_1	D_2	I_s	V_L
OFF	ON	OFF	ON	$= -I_L$	$= +v_i$
$V_{SCR_1} = v_i$	$V_{SCR_2} = 0$	$V_{d_1} = v_i$	$V_{d_2} = 0$		
$I = 0$	$I = I_L$	$I = 0$	$I = I_L$		

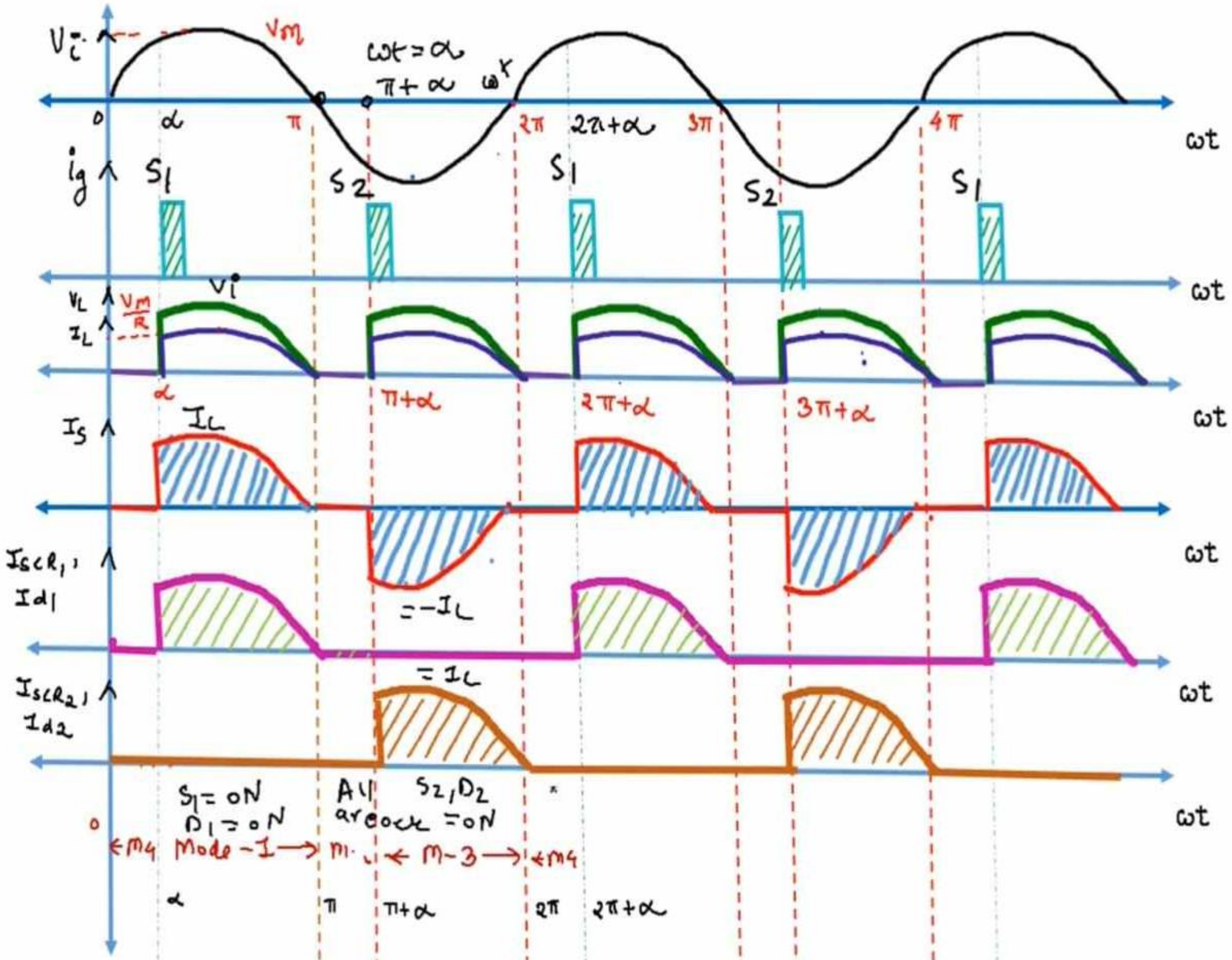
Semi Converter/Half Controlled Converter(with Resistive Load)

Mode IV





S1	S2	D1	D2	Is	VL
OFF	OFF	OFF	OFF	=0	=0
I=0	I=0	I=0	I=0		



Vi
Vm
ωt = α
π + α
0
α
π
2π
2π+α
3π
4π
ωt
ig
S1
S2
S1
S2
S1
VL
IL
Vm/R
α
π+α
2π+α
3π+α
IS
IL
ISCR1, Id1
= -IL
= IL
ISCR2, Id2
S1 = ON
D1 = ON
All are off
S2, D2 = ON
Mode - I
M-3
α
π
π+α
2π
2π+α

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Symmetrical Configuration of Semi Converter

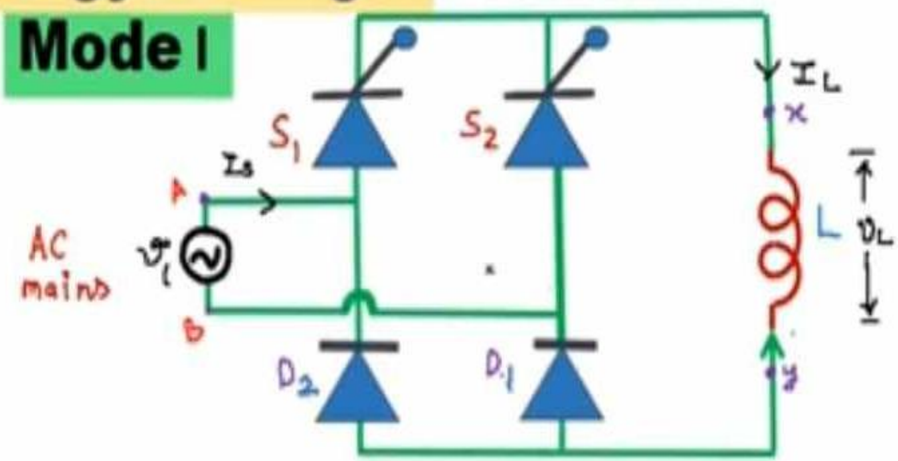
- **Mode I**: $\alpha \leq \omega t \leq \pi$
- **Mode II**: $\pi \leq \omega t \leq \pi + \alpha$
- **Mode III**: $\pi + \alpha \leq \omega t \leq 2\pi$
- **Mode IV**: $2\pi \leq \omega t \leq 2\pi + \alpha$

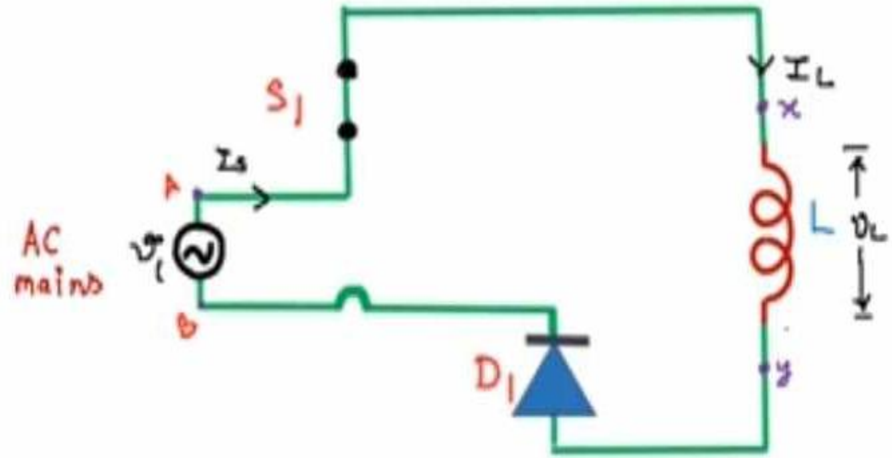
We have considered load to be highly inductive , therefore the load current is assumed to continuous and ripple free.

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Energy Storage

Mode I



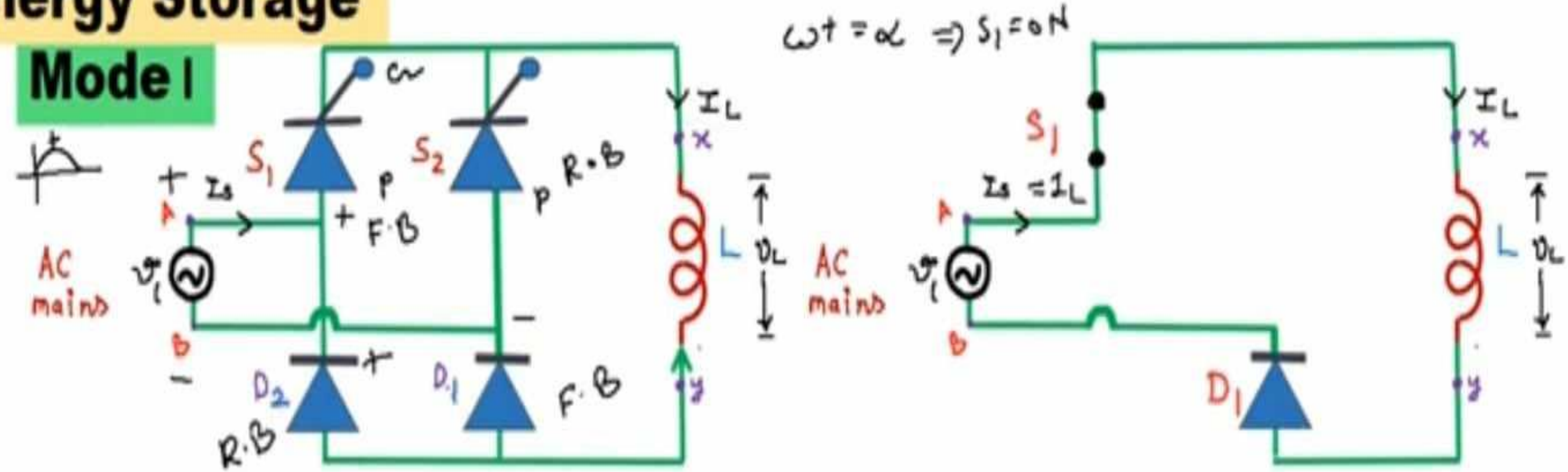


ON	OFF	ON	OFF		
S_1	S_2	D_1	D_2	I_S	V_L
$V_{SCR_1} = 0$	$V_{SCR_2} = V_i$	$V_{d_1} = 0$	$V_{d_2} = V_i$	$= I_L$	$= V_i$
$I_{SCR_1} = I_L$	$I_{SCR_2} = 0$	$I_{d_1} = I_L$	$I_{d_2} = 0$		

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Energy Storage

Mode I

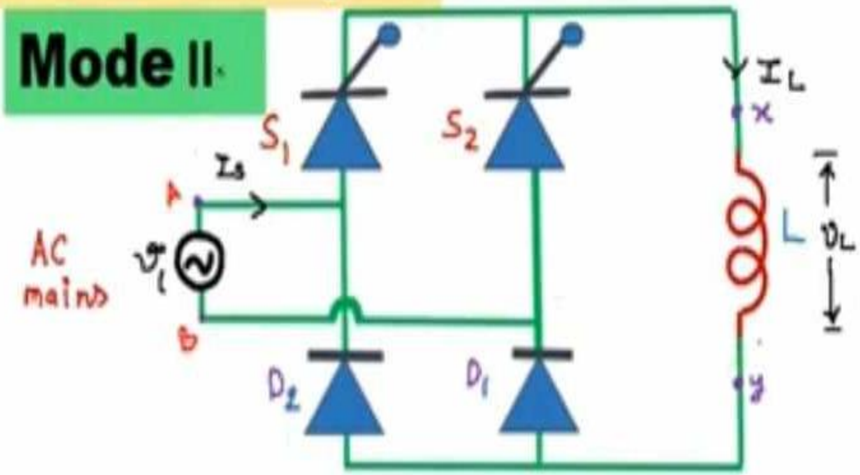


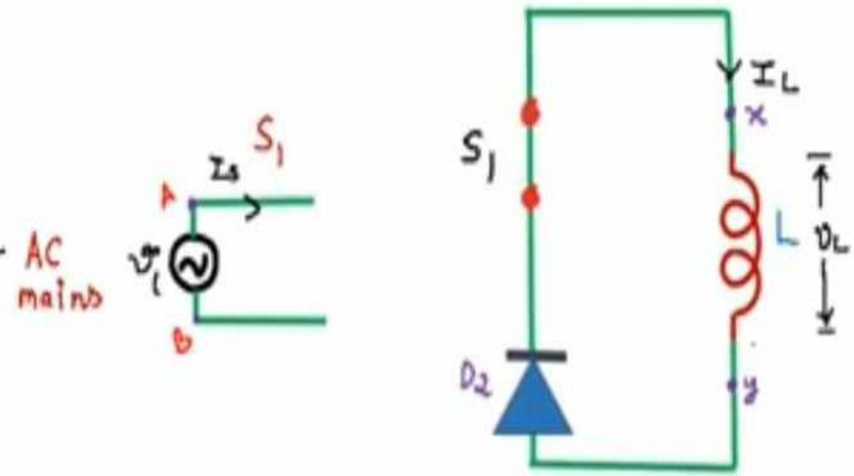
	ON	OFF	ON	OFF			
	S_1	S_2	D_1	D_2	I_s	V_L	
	$V_{SCR_1} = 0$	$V_{SCR_2} = V_i$	$V_{d_1} = 0$	$V_{d_2} = V_i$	$= I_L$	$= V_i$	$\omega t = \alpha$
	$I_{SCR_1} = I_L$	$I_{SCR_2} = 0$	$I_{d_1} = I_L$	$I_{d_2} = 0$			

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Free Wheeling

Mode II





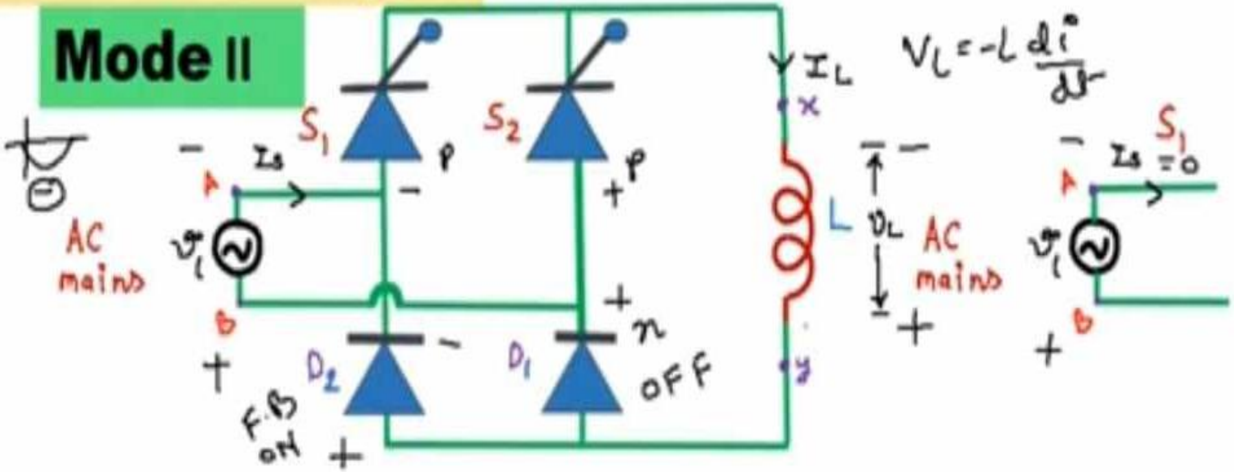
ON	OFF	OFF	ON		
S_1	S_2	D_1	D_2	I_s	V_L
$I_{scr_1} = I_L$	$I_{scr_2} = 0$	$I_{d_1} = 0$	$I_{d_2} = I_L$	$= 0$	$= 0$
$V_{scr_1} = 0$	$V_{scr_2} = V_i$	$V_{d_1} = V_i$	$V_{d_2} = 0$		

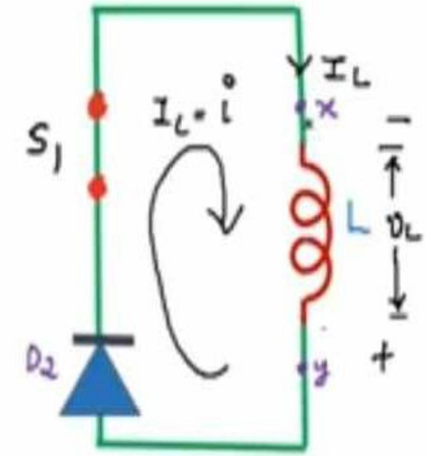
Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Free Wheeling

Mode II

$\omega t = \pi + \alpha$





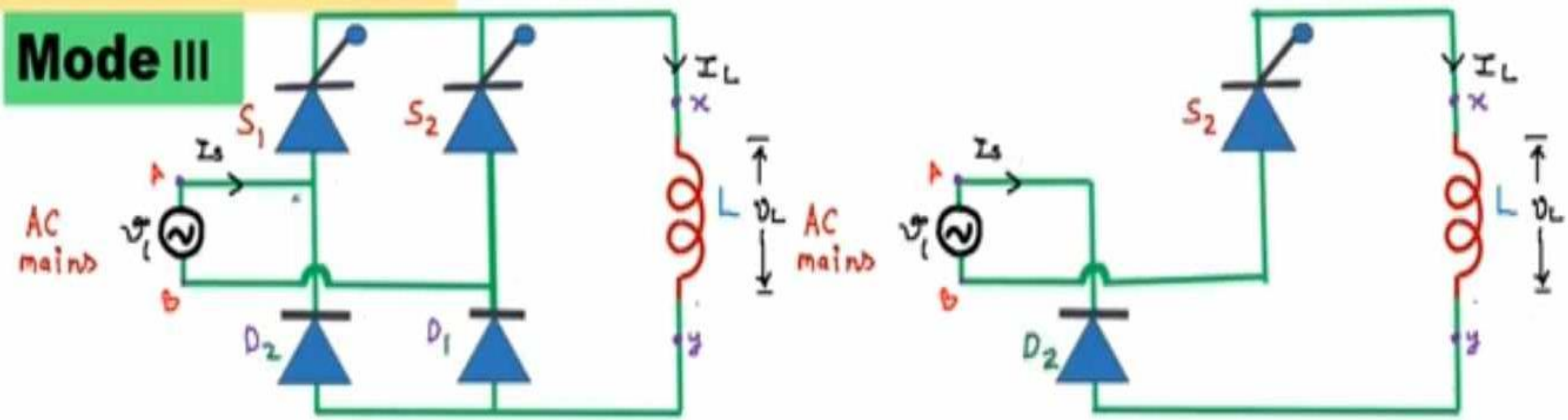
$V_L = 0$

ON	OFF	OFF	ON		
S_1	S_2	D_1	D_2	I_s	V_L
$I_{scr_1} = I_L$	$I_{scr_2} = 0$	$I_{d_1} = 0$	$I_{d_2} = I_L$	$= 0$	$= 0$
$V_{scr_1} = 0$	$V_{scr_2} = V_i$	$V_{d_1} = V_i$	$V_{d_2} = 0$		

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Line Commutation

Mode III

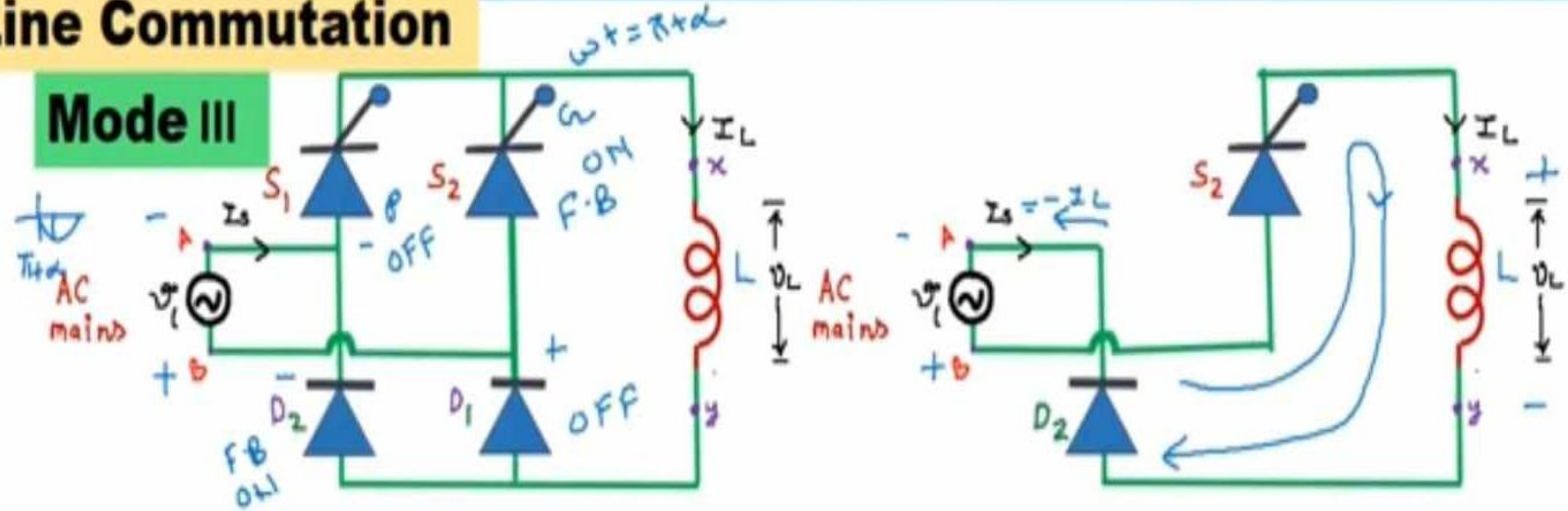


OFF	ON	OFF	ON		
S1	S2	D1	D2	Is	VL
$I_{scr_1} = 0$	$I_{scr_2} = I_L$	$I_{d_1} = 0$	$I_{d_2} = I_L$	$-I_L$	V_i
$V_{scr_1} = V_i$	$V_{scr_2} = 0$	$V_{d_1} = V_i$	$V_{d_2} = 0$		

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Line Commutation

Mode III

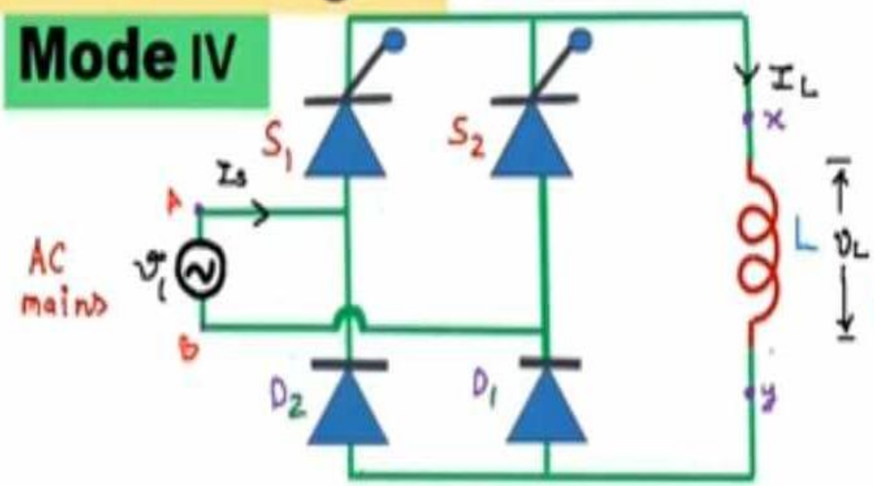


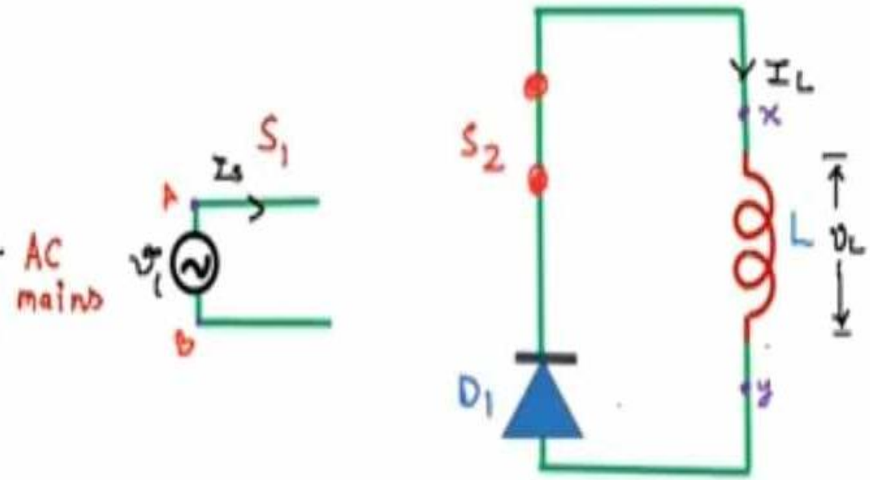
OFF	ON	OFF	ON		
S1	S2	D1	D2	Is	VL
$I_{scr_1} = 0$	$I_{scr_2} = I_L$	$I_{d_1} = 0$	$I_{d_2} = I_L$	$-I_L$	V_i
$V_{scr_1} = V_i$	$V_{scr_2} = 0$	$V_{d_1} = V_i$	$V_{d_2} = 0$		

Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Free Wheeling

Mode IV



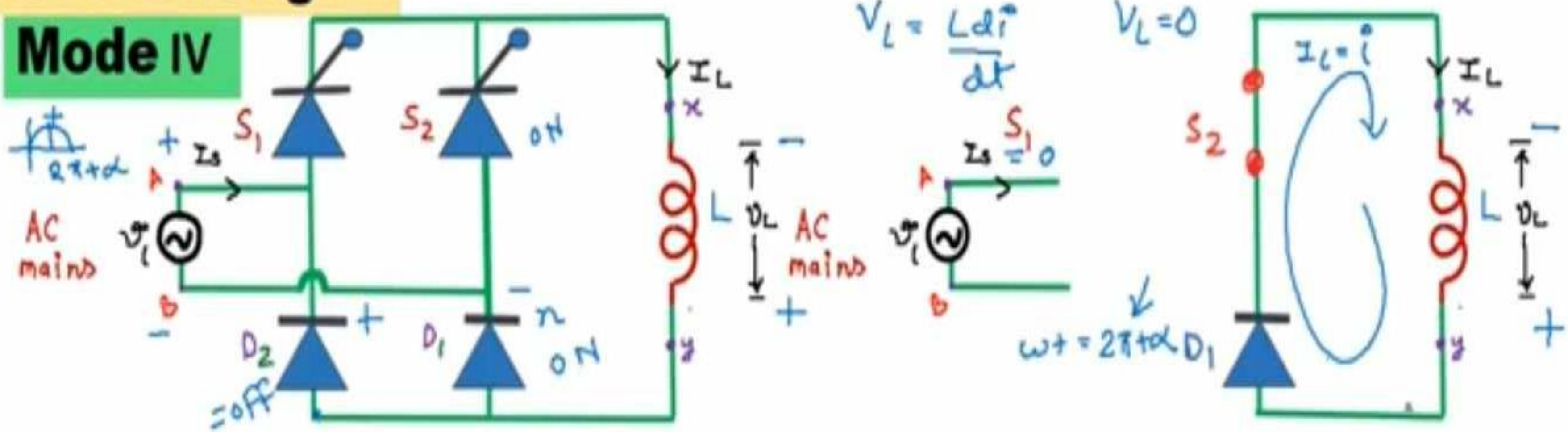


OFF	ON	ON	OFF		
S_1	S_2	D_1	D_2	I_s	V_L
$I_{scr_1} = 0$	$I_{scR_2} = I_L$	$I_{d_1} = I_L$	$I_{d_2} = 0$	$= 0$	$= 0$
$V_{scr_1} = V_i$	$V_{scR_2} = 0$	$V_{d_1} = 0$	$V_{d_2} = V_i$		

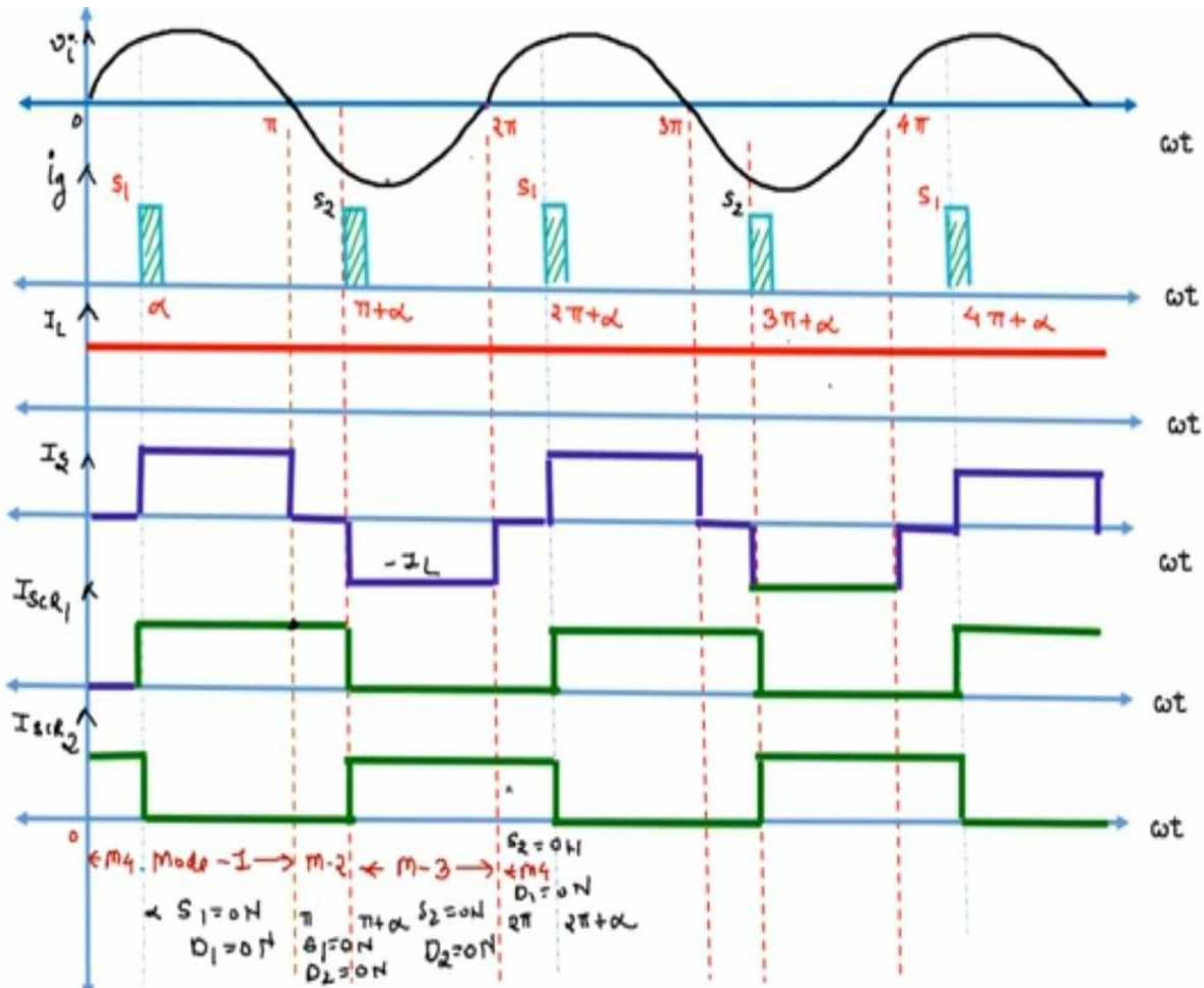
Semi Converter/Half Controlled Converter(Symmetrical Configuration)

Free Wheeling

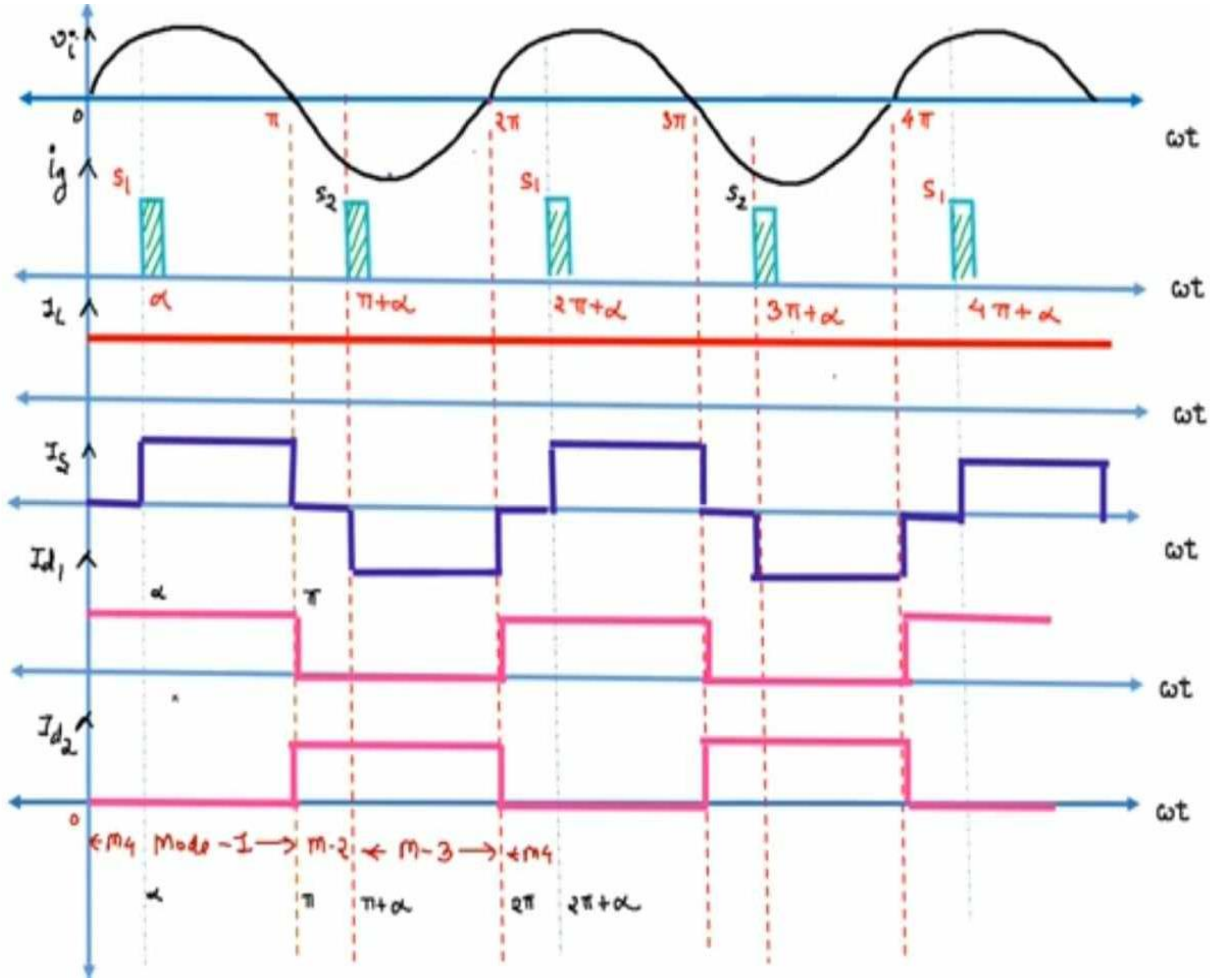
Mode IV



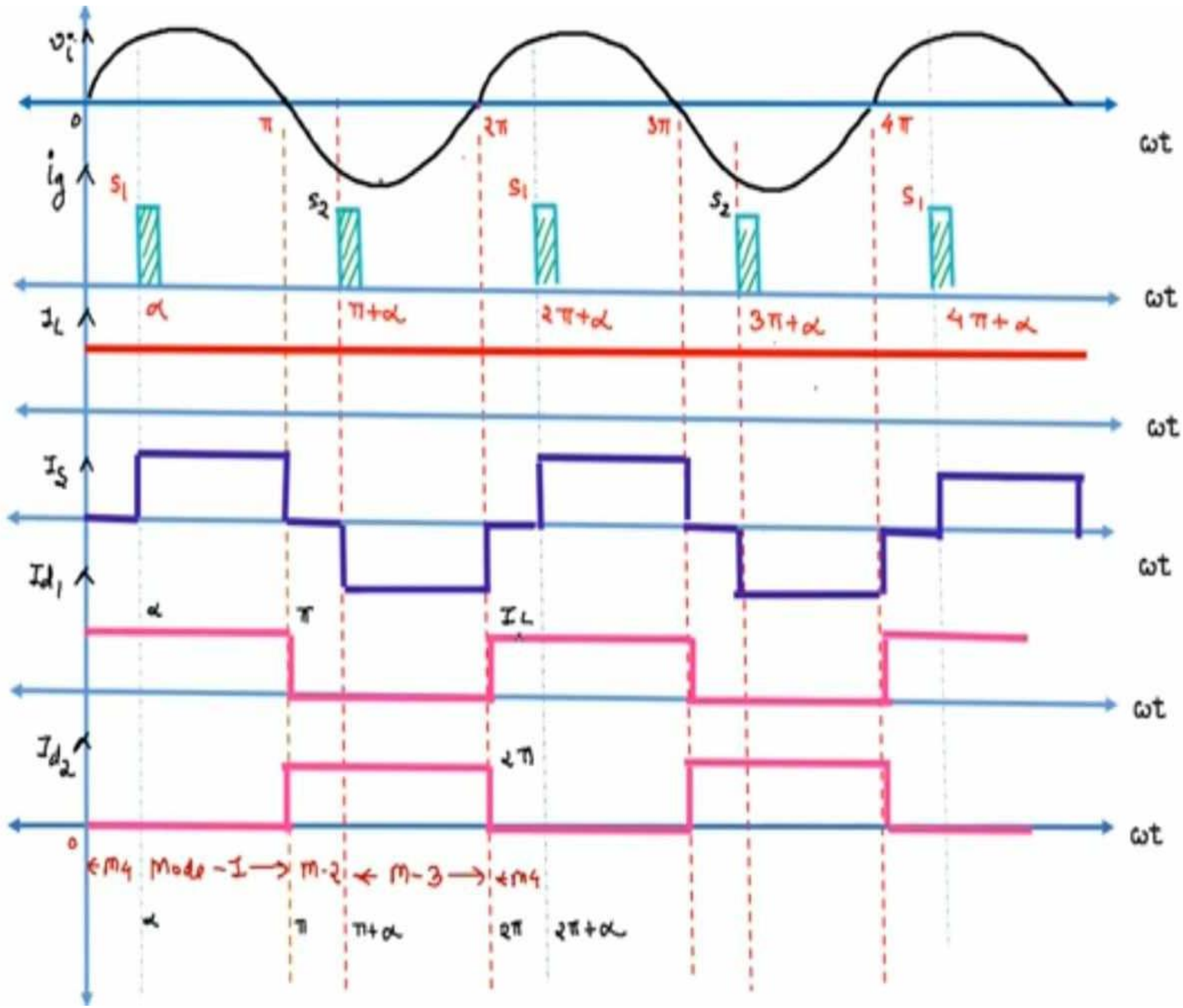
OFF	ON	ON	OFF		
S1	S2	D1	D2	Is	VL
$I_{SCR_1} = 0$	$I_{SCR_2} = I_L$	$I_{d_1} = I_L$	$I_{d_2} = 0$	$= 0$	$= 0$
$V_{SCR_1} = V_i$	$V_{SCR_2} = 0$	$V_{d_1} = 0$	$V_{d_2} = V_i$		



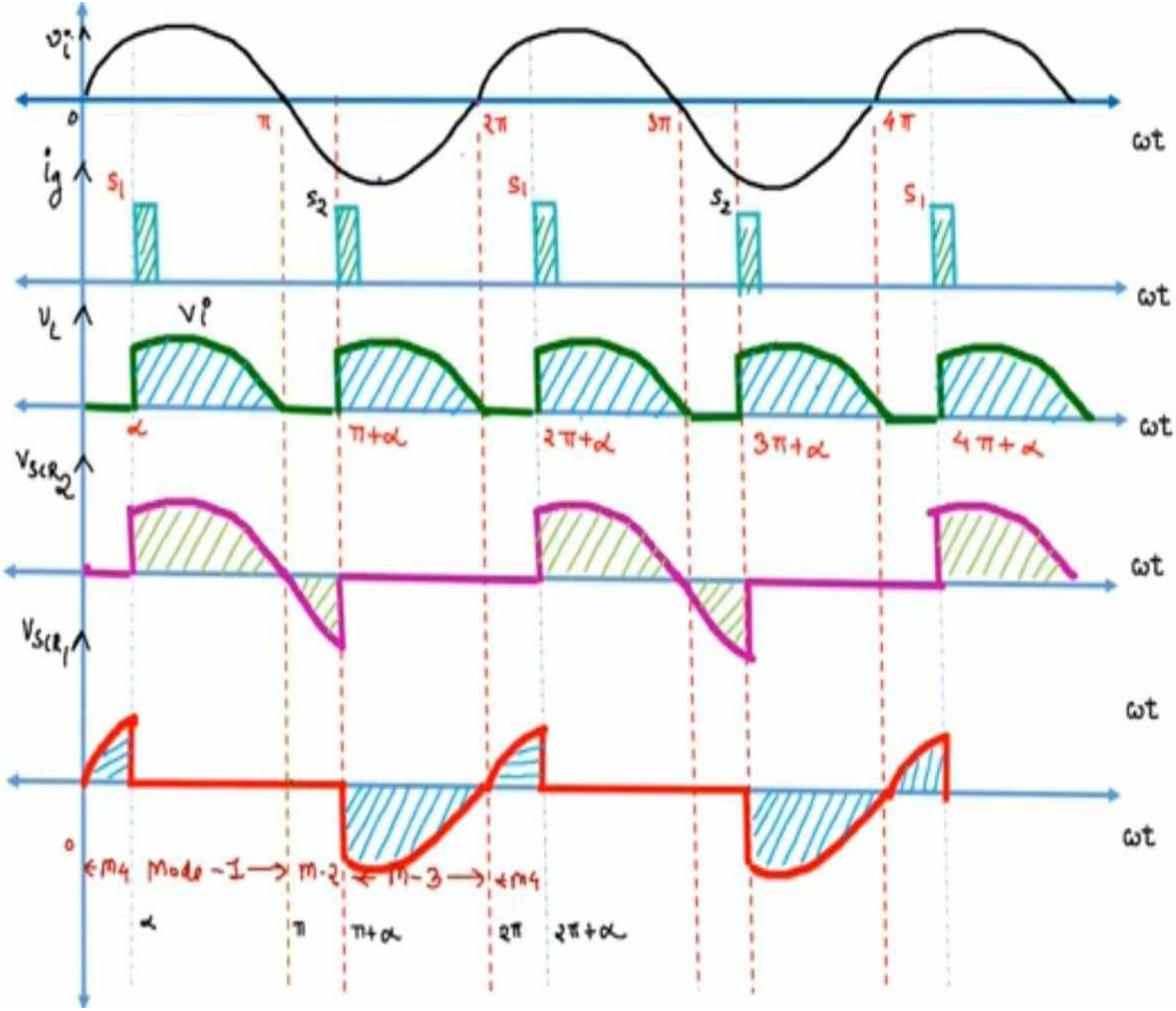
v_i
0
π
2π
3π
4π
ωt
i_g
S_1
S_2
α
π+α
2π+α
3π+α
4π+α
I_L
I_s
$-I_L$
I_{SCR_1}
I_{SCR_2}
← M4 Mode - I → M-2 ← M-3 → ← M4
S_2 = ON
D_1 = ON
α S_1 = ON
D_1 = ON
π
S_1 = ON
D_2 = ON
π+α S_2 = ON
D_2 = ON
2π
2π+α



v_i
i_g
S_1
S_2
S_1
S_2
S_1
α
$\pi+\alpha$
$2\pi+\alpha$
$3\pi+\alpha$
$4\pi+\alpha$
0
π
2π
3π
4π
I_L
I_S
I_{d_1}
I_{d_2}
ωt
←m4 Mode-1→ m-2 ← m-3 → ←m4
α
π
$\pi+\alpha$
2π
$2\pi+\alpha$



v_i
0
π
2π
3π
4π
ωt
i_g
S_1
S_2
α
π+α
2π+α
3π+α
4π+α
I_L
I_S
I_{d_1}
I_L
I_{d_2}
← m4 Mode - I → m-2 ← m-3 → ← m4



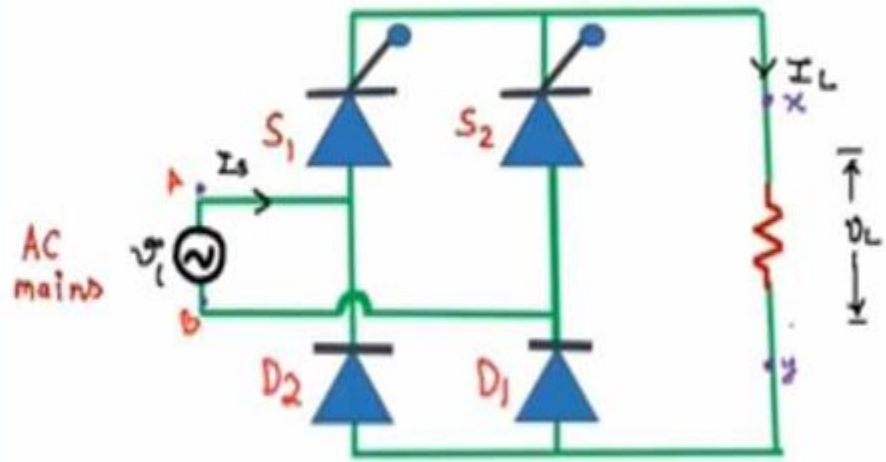
vi
ωt
ig
S1
S2
VL
Vi
α
π+α
2π+α
3π+α
4π+α
VSCR2
VSCR1
Mode-1
m-2
m-3
m4
π
2π
3π
4π

Analysis of

Half Controlled Converter

Or

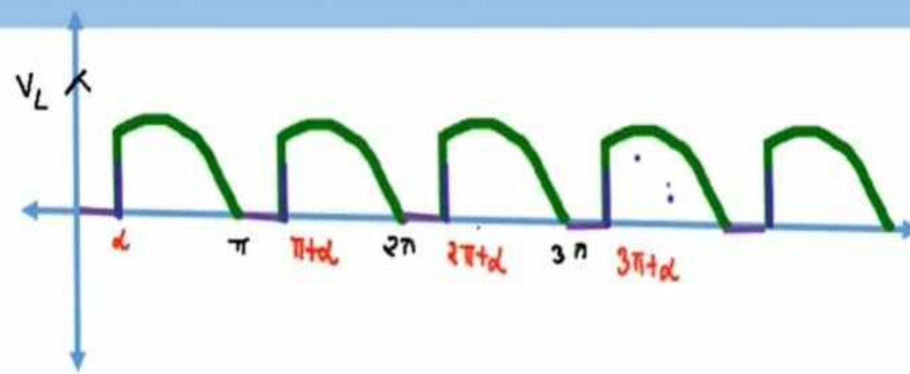
Semi-Converter



- **Average dc voltage and current**
- **Rms output voltage and current**

Analysis of Semi-Converter with Resistive Load

Average Output Voltage



$$V_{dc} = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \, d\omega t$$

$$= \frac{V_m}{\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

$$= -\frac{V_m}{\pi}\left[\cos\omega t\right]_{\alpha}^{\pi} = -\frac{V_m}{\pi}\left(-1-\cos\alpha\right] = +\frac{V_m}{\pi}\left(1+\cos\alpha\right)$$

Analysis of Semi-Converter with Resistive Load

Average Output Voltage

$$I = \frac{V}{R}$$

$$I_{Ldc} = \frac{V_{Ldc}}{R} = \frac{\frac{V_m}{\pi}(1+\cos\alpha)}{R}$$

$$I_L dc = \frac{V_m}{\pi R}(1+\cos\alpha)$$

Analysis of Semi-Converter with Resistive Load

Rms Output Voltage

$$V_{Lrms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} V_m^2 \sin^2\omega t \, d\omega t}$$

$$= \sqrt{\frac{V_m^2}{\pi}\int_{\alpha}^{\pi} \sin^2\omega t \, d\omega t} \qquad \left[\because \sin^2\omega t = \frac{1-\cos 2\omega t}{2}\right]$$

$$= \sqrt{\frac{V_m^2}{\pi}\int_{\alpha}^{\pi} \frac{1-\cos 2\omega t}{2} \, d\omega t}$$

$$V_{Lrms} = \sqrt{\frac{V_m^2}{\pi}\left[\frac{\omega t}{2} - \frac{\sin 2\omega t}{2\times 2}\right]_{\alpha}^{\pi}}$$

$$V_{Lrms} = \sqrt{\frac{V_m^2}{2\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_{\alpha}^{\pi}}$$

Analysis of Semi-Converter with Resistive Load

Rms Output Voltage

$$V_{Lrms} = \sqrt{\frac{V_m^2}{2\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_\alpha^\pi}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\left[\pi-\alpha-0+\frac{\sin 2\alpha}{2}\right]}$$

$$V_{Lrms} = \sqrt{\frac{V_m^2}{2\pi}\left[\pi-\alpha+\frac{\sin 2\alpha}{2}\right.}$$

$$V_{Lrms} = \frac{V_m}{\sqrt{2}}\sqrt{\frac{1}{\pi}\left(\pi-\alpha+\frac{\sin 2\alpha}{2}\right)}$$

$\frac{V_m}{\sqrt{2}}$ = rms supply v/g = V_{srms}

$$V_{Lrms} = V_{srms}\sqrt{\frac{1}{\pi}\left(\pi-\alpha+\frac{\sin 2\alpha}{2}\right)}$$

$$I_{Lrms} = \frac{V_{s\,rms}\sqrt{\frac{1}{\pi}\left(\pi-\alpha+\frac{\sin 2\alpha}{2}\right)}}{R}$$

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

A-Symmetrical Configuration of Semi Converter

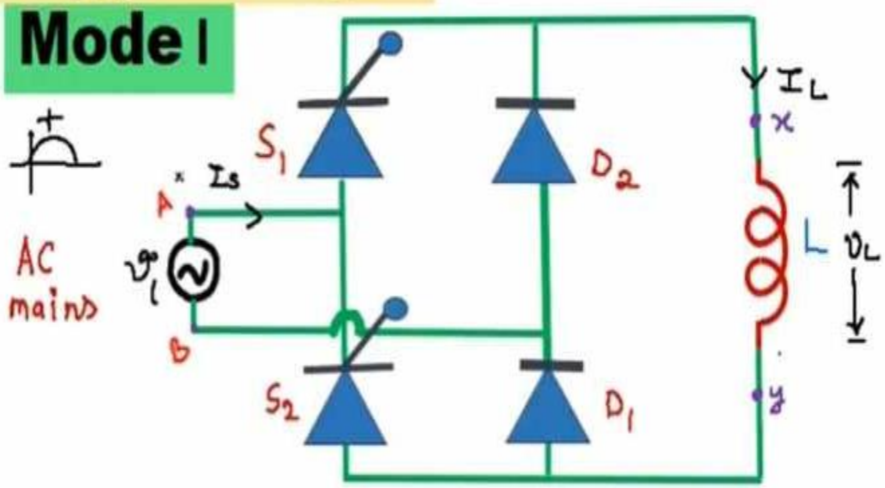
- **Mode I**: $\alpha \leq \omega t \leq \pi$
- **Mode II**: $\pi \leq \omega t \leq \pi + \alpha$
- **Mode III**: $\pi + \alpha \leq \omega t \leq 2\pi$
- **Mode IV**: $2\pi \leq \omega t \leq 2\pi + \alpha$

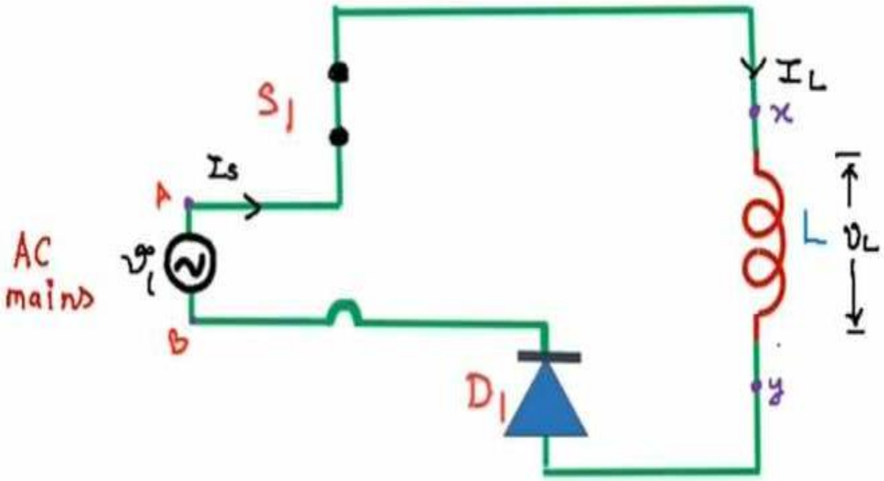
We have considered load to be highly inductive , therefore the load current is assumed to continuous and ripple free.

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Energy Storage

Mode I



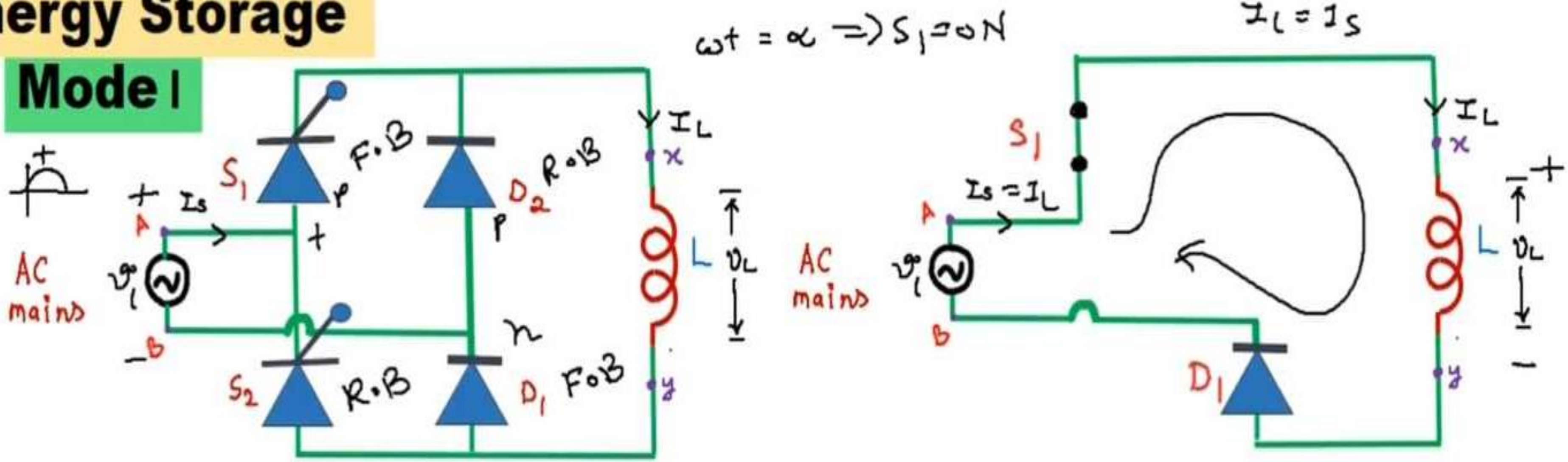


S1 (ON)	S2 (OFF)	D1 (ON)	D2 (OFF)	Is	VL
$V_{SCR_1} = 0$	$V_{SCR_2} = V_i$	$V_{d_1} = 0$	$V_{d_2} = V_i$	$= I_L$	$= v_i$
$I_{SCR_1} = I_L$	$I_{SCR_2} = 0$	$I_{d_1} = I_L$	$I_{d_2} = 0$		

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Energy Storage

Mode I

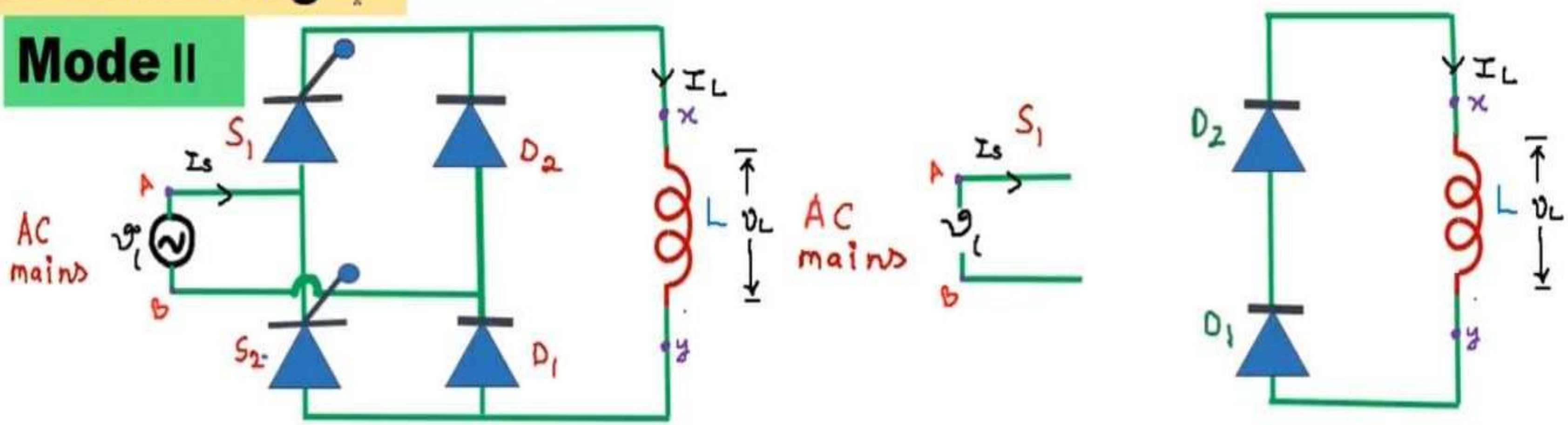


ON	OFF	ON	OFF		
S_1	S_2	D_1	D_2	I_S	V_L
$V_{SCR_1} = 0$	$V_{SCR_2} = V_i$	$V_{d_1} = 0$	$V_{d_2} = V_i$	$= I_L$	$= V_i$
$I_{SCR_1} = I_L$	$I_{SCR_2} = 0$	$I_{d_1} = I_L$	$I_{d_2} = 0$		

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Free Wheeling

Mode II

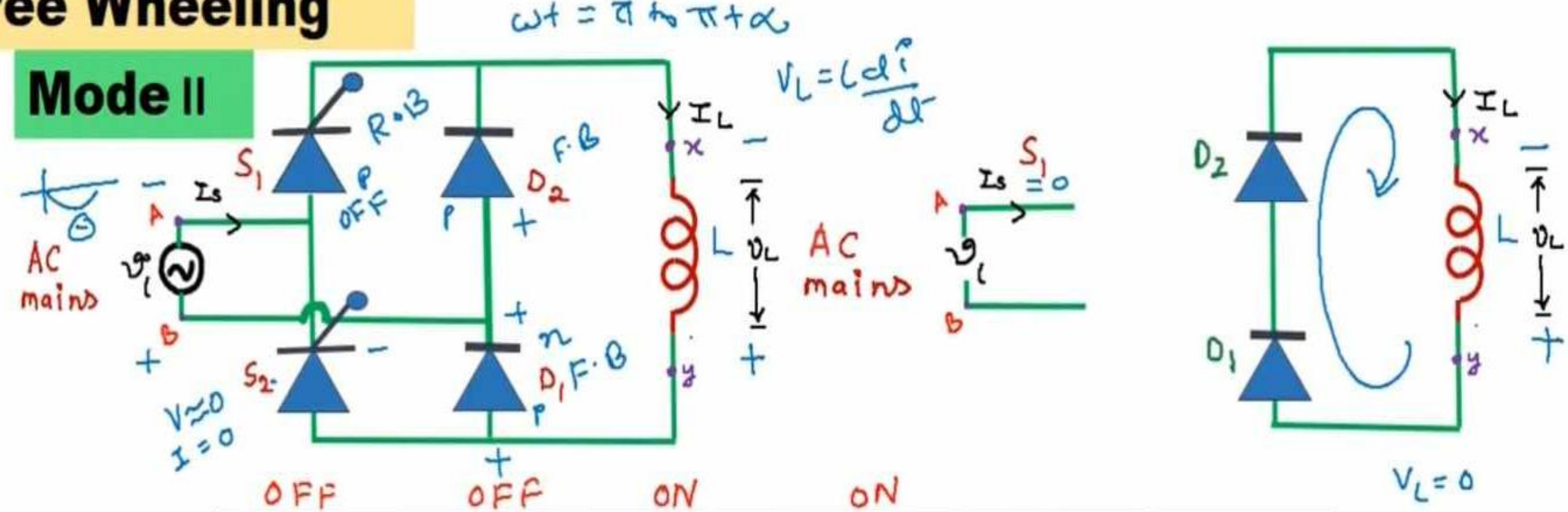


S1	S2	D1	D2	Is	VL
OFF	OFF	ON	ON		

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Free Wheeling

Mode II

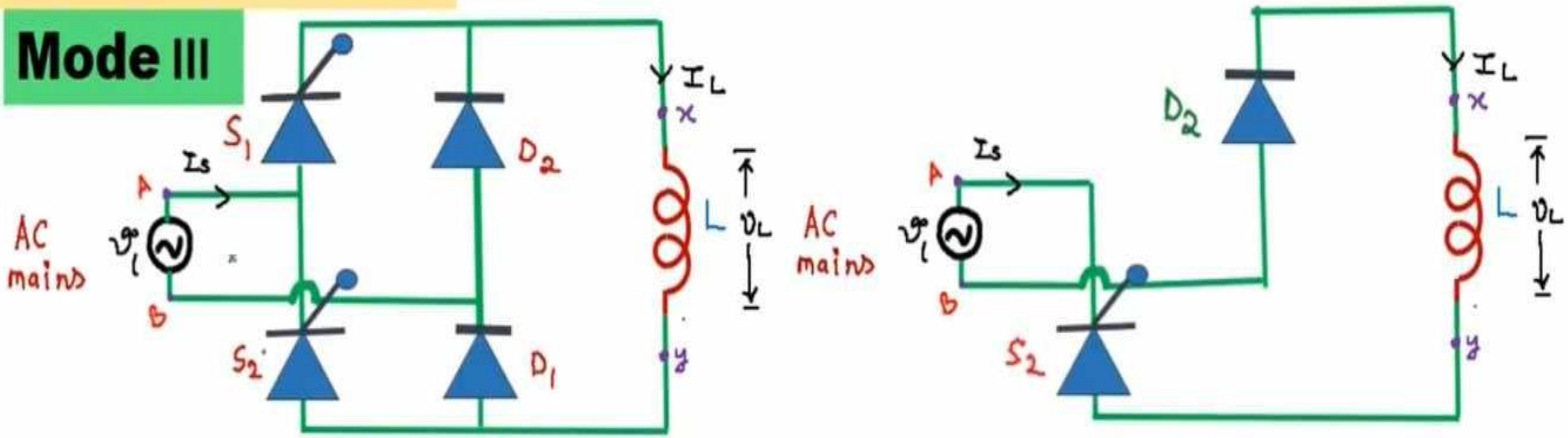


OFF	OFF	ON	ON		
S_1	S_2	D_1	D_2	I_s	V_L
$V_{SCR_1} = v_i$	$V_{SCR_2} \approx 0$	$V_{d_1} = 0$	$V_{d_2} = 0$	$= 0$	
$I_{SCR_1} = 0$	$I_{SCR_2} = 0$	$I_{d_1} = I_L$	$I_{d_2} = I_L$		

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Line Commutation

Mode III

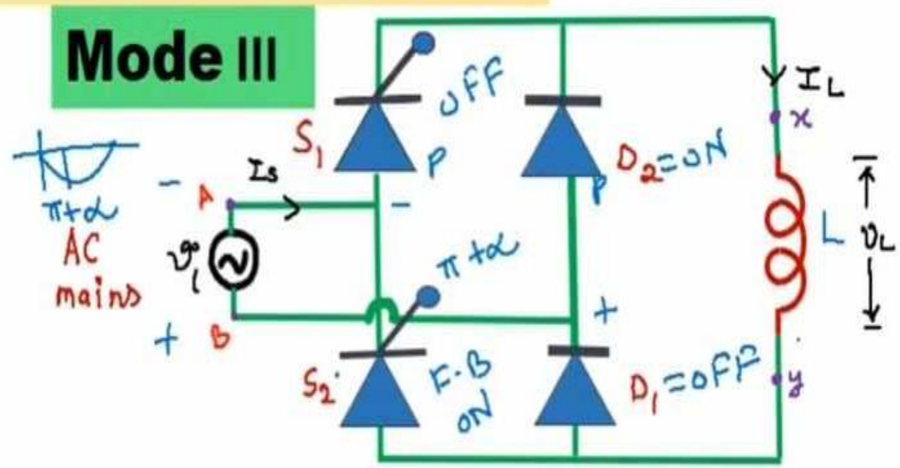


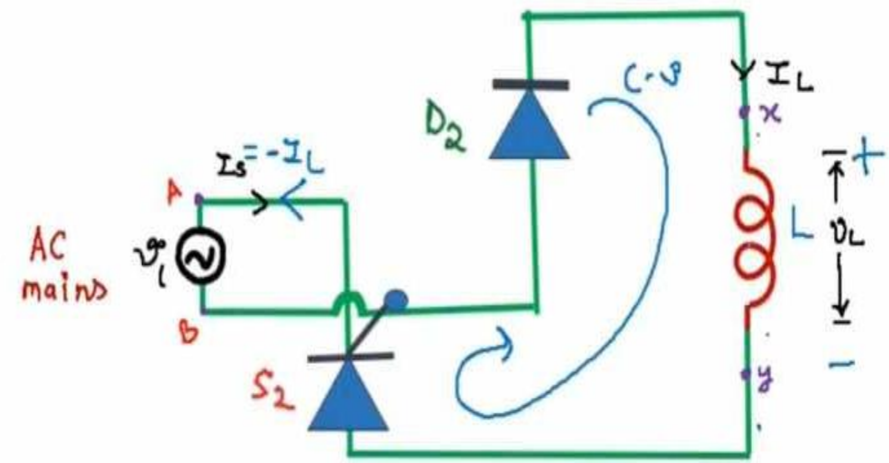
OFF	ON	OFF	ON		
S_1	S_2	D_1	D_2	I_S	V_L

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Line Commutation

Mode III



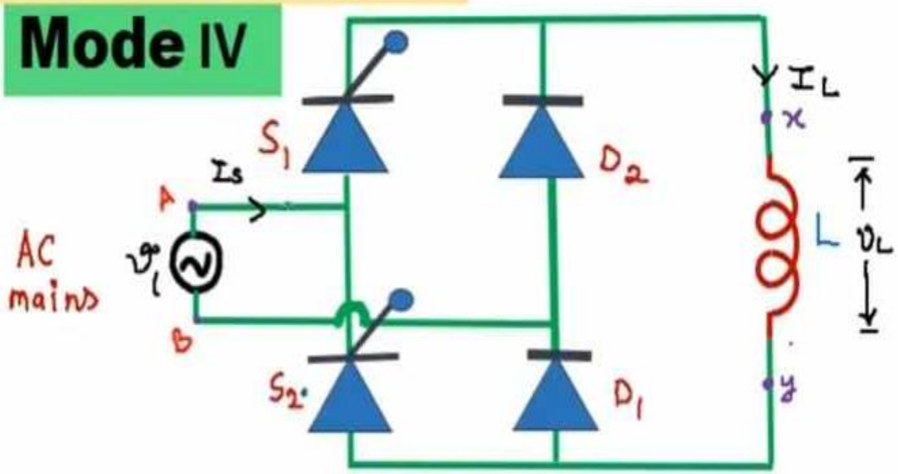


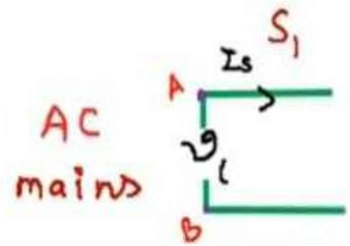
OFF	ON	OFF	ON		
S_1	S_2	D_1	D_2	I_S	V_L
$V_{SCR_1} = v_i$	$V_{SCR_2} = 0$	$V_{d_1} = v_i$	$V_{d_2} = 0$	$= -I_L$	$= v_i$
$I_{SCR_1} = 0$	$I_{SCR_2} = I_L$	$I_{d_1} = 0$	$I_{d_2} = I_L$		

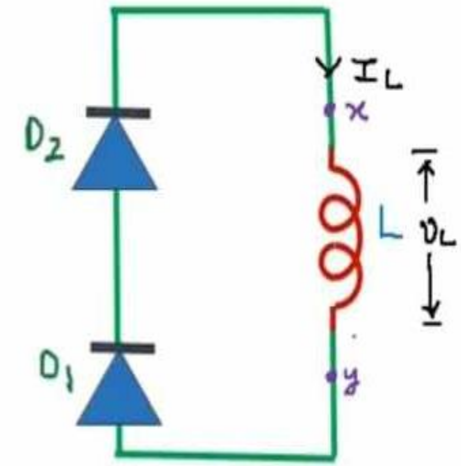
Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

Free Wheeling

Mode IV





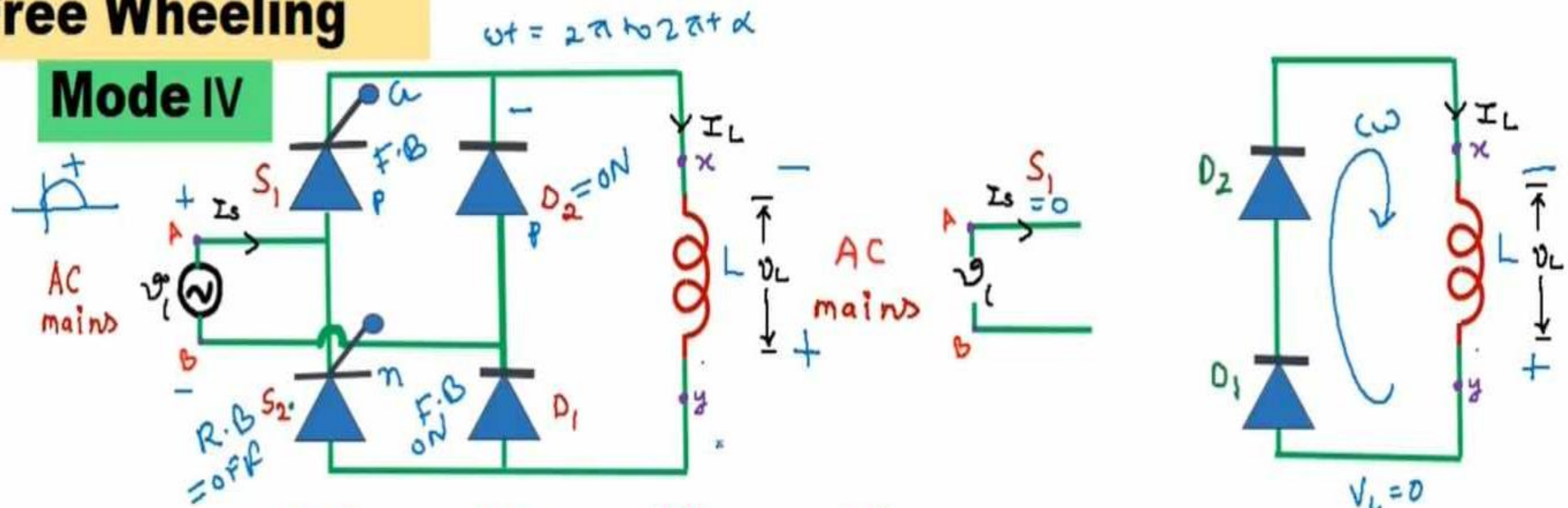


S_1	S_2	D_1	D_2	I_s	V_L
OFF	OFF	ON	ON		

Semi Converter/Half Controlled Converter(Asymmetrical Configuration)

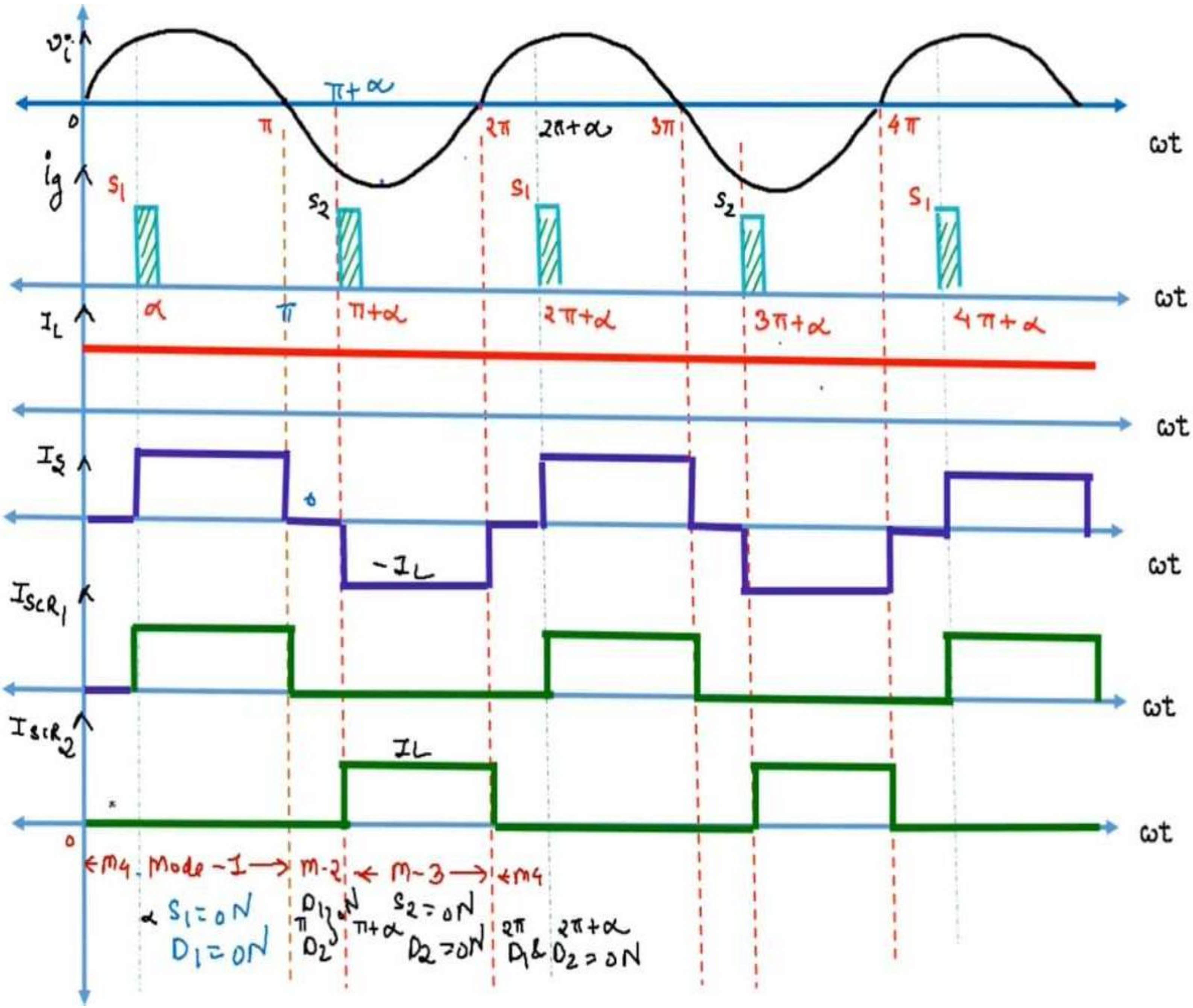
Free Wheeling

Mode IV

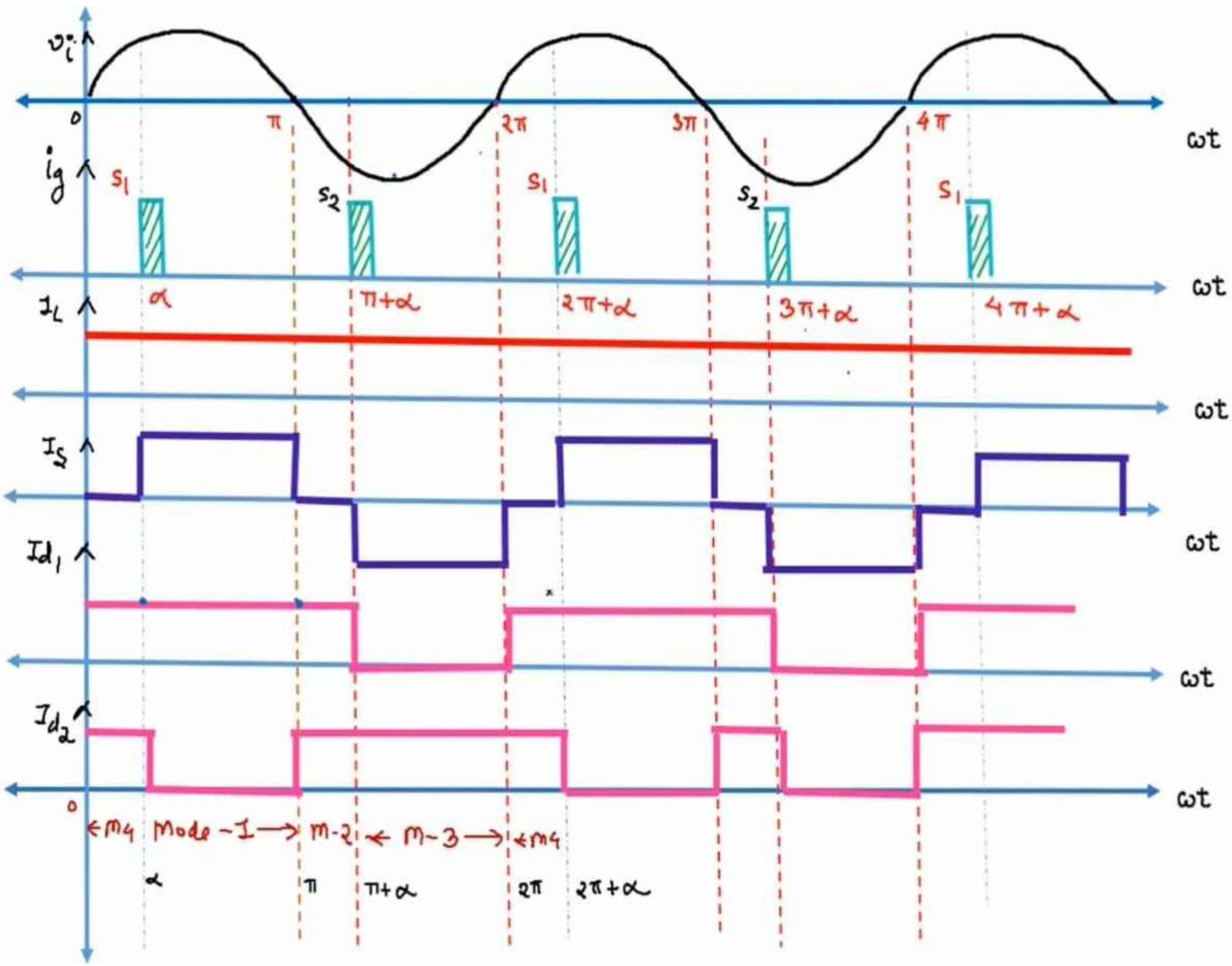


OFF OFF ON ON

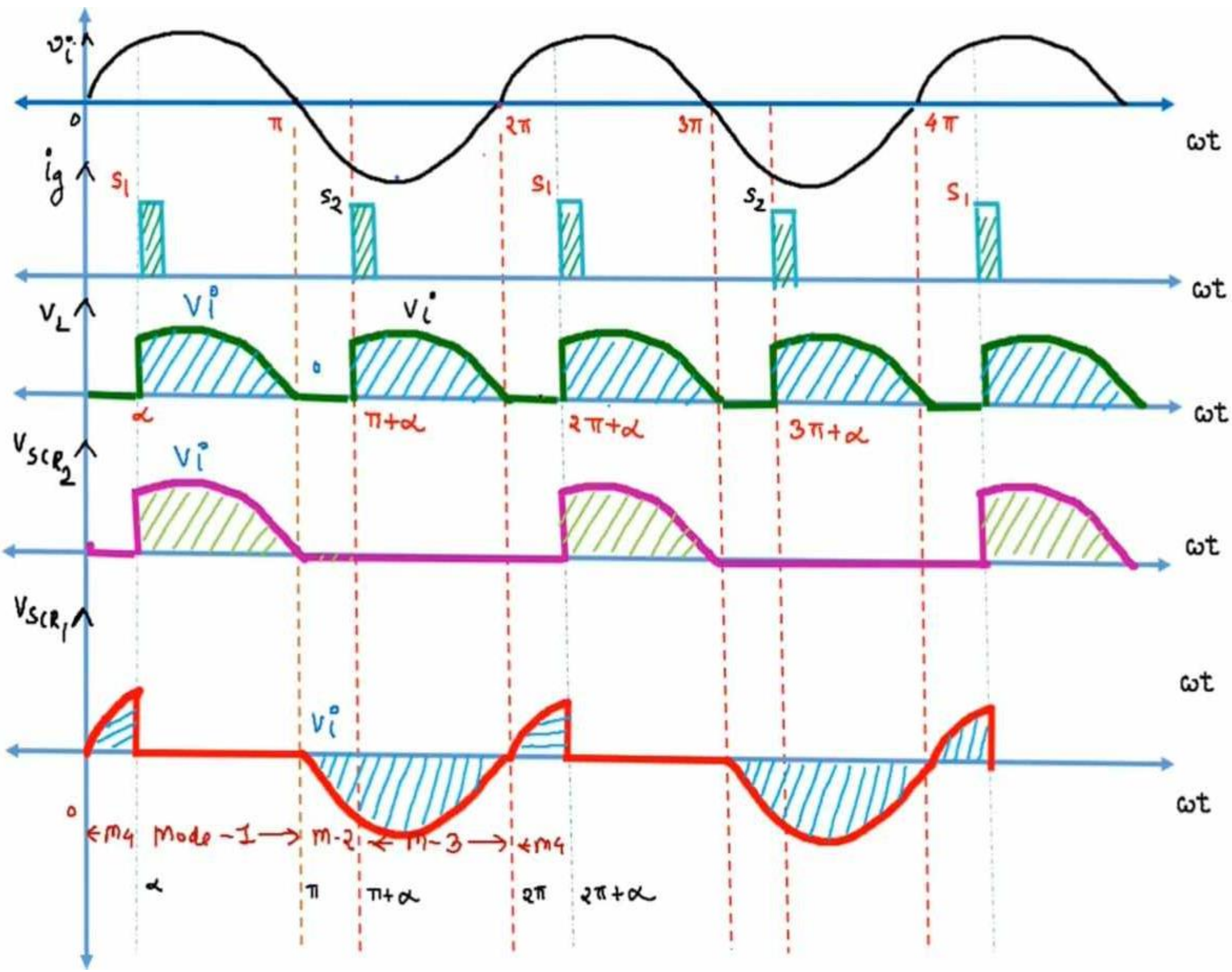
S_1	S_2	D_1	D_2	I_S	V_L
$V_{SCR_1}=0$	$V_{SCR_2}=v_i$	$V_{d_1}=0$	$V_{d_1}=0$	$=0$	$=0$
$I_{SCR_1}=0$	$I_{SCR_2}=0$	$I_{d_1}=I_L$	$I_{D_2}=I_L$		



vi
0
π
π+α
2π
2π+α
3π
4π
ωt
ig
S1
S2
α
π+α
2π+α
3π+α
4π+α
IL
Is
-IL
IscR1
IscR2
IL
m4 Mode-1 m-2 m-3 m4
α S1=ON D1=ON
π D1 & D2 ON
π+α S2=ON D2=ON
2π 2π+α D1 & D2 = ON

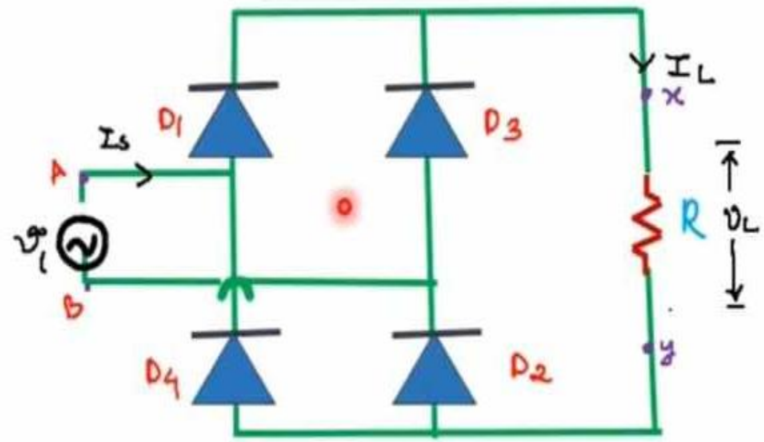


v_i
0
π
2π
3π
4π
ωt
i_g
S_1
S_2
α
π+α
2π+α
3π+α
4π+α
I_L
I_S
I_{d_1}
I_{d_2}
←M4 Mode-1→ M-2 ← M-3 → ←M4
α
π
π+α
2π
2π+α

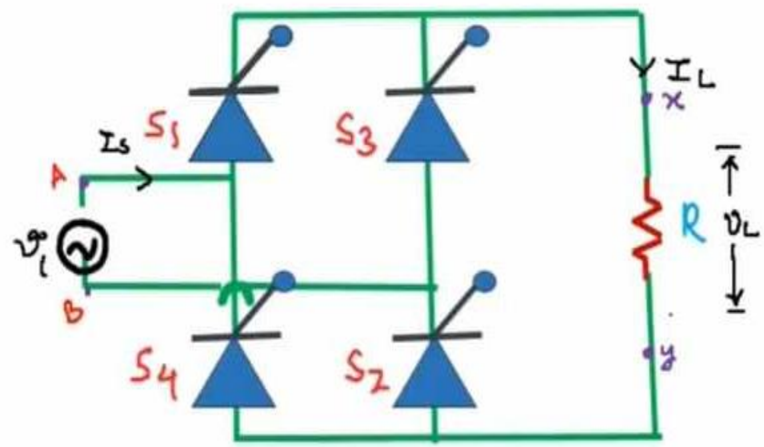


v_i
i_g
V_L
V_{SCR_2}
V_{SCR_1}
ωt
0
π
2π
3π
4π
S_1
S_2
v_i
α
π+α
2π+α
3π+α
m4
Mode-1
m-2
m-3
m4

Difference between Un-controlled & Controlled Rectifiers



Un-Controlled Converters

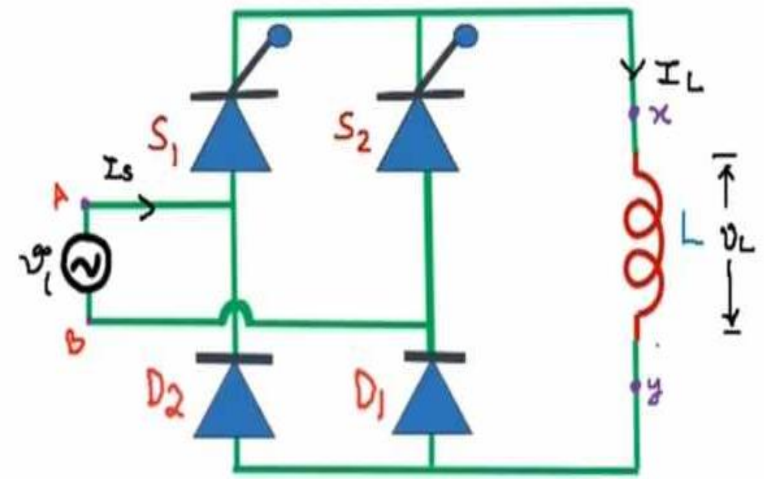


Controlled Converters

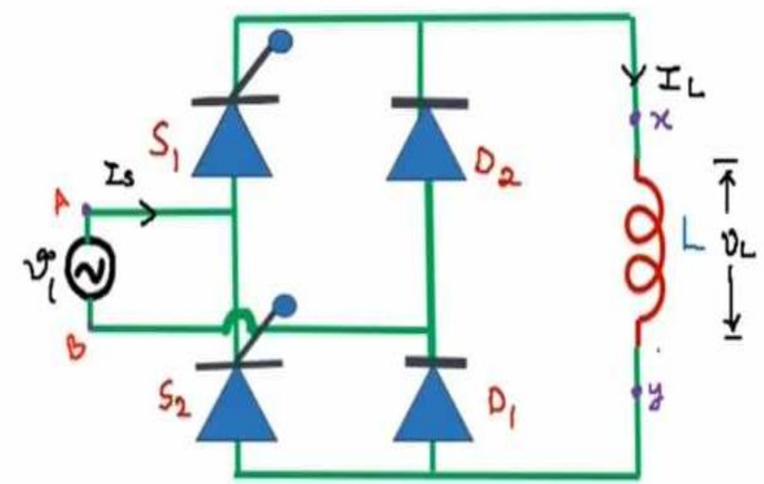
Difference between Uncontrolled & Controlled Rectifiers/Converters

S . No.	Parameter	Uncontrolled Rectifiers	Controlled Rectifiers
1.	Devices used	Only Diodes	Combination of SCRs & diodes/ only SCRs
2.	Devices Turn ON at	At zero crossing of supply voltage	At firing angle/delay angle
3.	Control of Load Power	Not possible	Possible
4.	Control circuit/Triggering circuit	Not Required	Required
5.	Quadrant of Operation	Only first quadrant	First or second quadrant
6.	Direction of Power flow	Source to Load only	Source to load & Load to source possible.
7.	Free wheeling Diode	Not necessary	Required
8.	Configuration	Half wave, Mid-point and Bridge	HWCR, FWCR, Semi-converter, Bridge & Mid-Point.
9.	Applications	Power supplies	DC motor Controllers, Battery chargers

Comparison of Symmetrical & Asymmetrical Configuration of SemiConverters



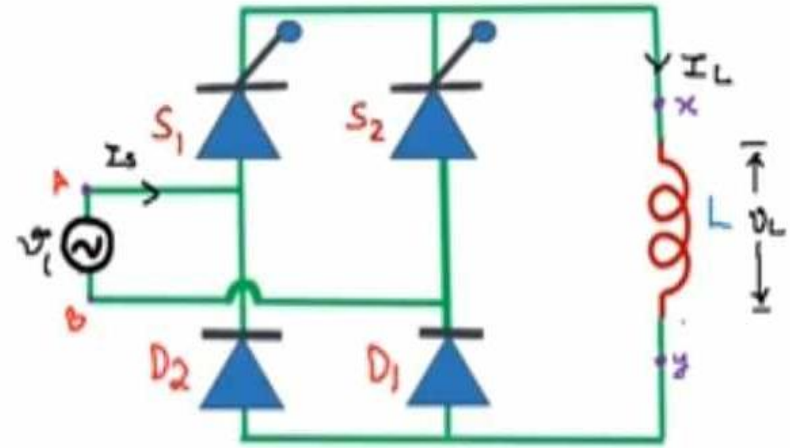
Symmetrical configuration



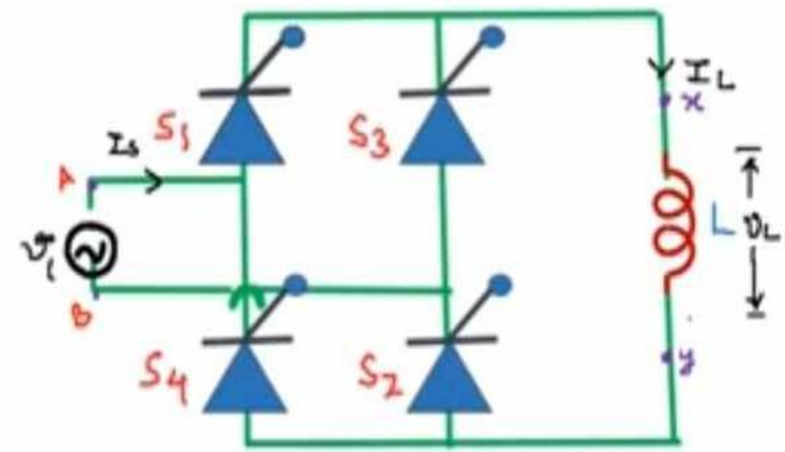
Asymmetrical configuration

S . No.	Parameter	Symmetrical	A-Symmetrical
1.	Devices used	Two SCRs and two Diodes	Two SCRs and two Diodes
2.	Conduction Angle	π radians	π -α radians
3.	Control of Load Power	Possible	Possible
4.	Control circuit/Triggering circuit	Due to common cathode connection, triggering pulsed not isolated from each other	Cathodes are at different potential, triggering pulses need to be isolated from each other.
5.	Quadrant of Operation	Only first quadrant	Only first quadrant
6.	Direction of Power flow	Source to Load only(unidirectional)	Source to Load only(unidirectional)
7.	Free wheeling Action	S_1D_2 & S_2D_1 (inherent not external)	D_1D_2 (inherent not external)
8.	Configuration	S_1D_2 & S_2D_1 connected on same leg	D_1D_2 & S_1S_2 connected on same leg

Comparison of Semi Converters/ Half Controlled Converters & Fully Controlled Converters



Semi-Converters



Fully Controlled Connverters

S . No.	Parameter	Half Controlled Converters/Semi C.	Fully Controlled Converters
1.	Power Circuit	Mixture of Diodes and SCRs	Only SCRs
2.	Conduction Angle	π radians(Sym.)/π -α radians(A-sym.)	π radians(R-L) /π -α radians(R)
3.	Power factor	Input power factor is more	Input power factor is less
4.	Control Level	DC output voltage has limited control level	DC output voltage has wider control level
5.	Free Wheeling	Present (require less reactive power)	Not needed
6.	Quadrant of Operation	Only first quadrant(only rectification)	Second quadrant(Rect. & Inv.)
7.	Direction of Power flow	Source to Load only(unidirectional)	Source to load & Load to source possible(Bi-dir.)
8.	Supply current	Quasi square wave	Square wave
9.	Configuration	Symmetrical and Asymmetrical	Mid Point and Bridge
10.	Uses	Only as Rectifiers	Inverters & Rectifiers