MADE EASY
ELECTRICAL ENGINEERING
POWER ELECTRONICS
BY-JAGDEESH SIR

Topics:

(i) Power semiconductor devices

(ii) Phase controlled rectifier (AC-DC) and Appl: Charging battery
DC Drive
solar cell

power semiconductor devices :-

(i) Power diode
(ii) SCR (thyristor)
(iii) LASCR
(iv) ASCR
(v) RCT
(vi) GTO
(vii) TRIAC
(viii) DIAC

power transistor (f↑)
③ → power BJT
① → power MOSFET
② → IGBT
└→ switching frequency order

cycloconv. ⇐ AC ⟶ DC ⟶ DC ⟶ AC

Power electronics :-

Static V-I characteristics and firing/gating circuits for thyristor, MOSFET, IGBT; DC to DC conversion: Buck and Buck-Boost converters; single and three phase configuration of uncontrolled rectifiers; voltage and current commutated Thyristor based converters; Bidirectional ac to dc voltage source converters; Magnitude and phase of line current harmonics for uncontrolled and thyristor based converters; power factor and distortion factor of ac to dc converters; VSI, CSI, PWM.

Topics :

(i) Power semiconductor devices

*(ii) Phase controlled Rectifiers (AC ⇄ DC)

and application : charging Battery : DC drive

: solar cell : HVDC

Solar energy can be stored in the form of DC system but our utility system are in AC system. so conversion is needed and this is possible by using phase controlled Rectifier. (converter).

Suppose we want to control the DC machine then phase controlled Rectifier is used.

*(iii) switched mode DC → DC converters (choppers)

*(iv) switched mode DC → AC converters (inverters)

(v) AC drive

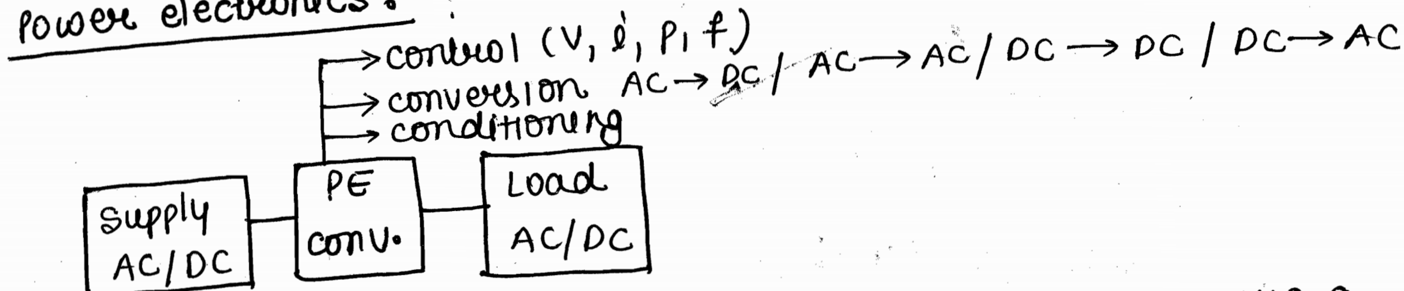
only for ESE

(vi) Resonant converters

(vii) High frequency T/F and Inductors for PE Application.

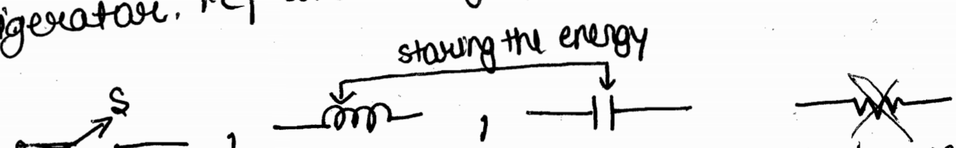
(viii) SMPS

Power electronics :- ?



Due to the mismatching of power in both side we require a device which is known as power converters.

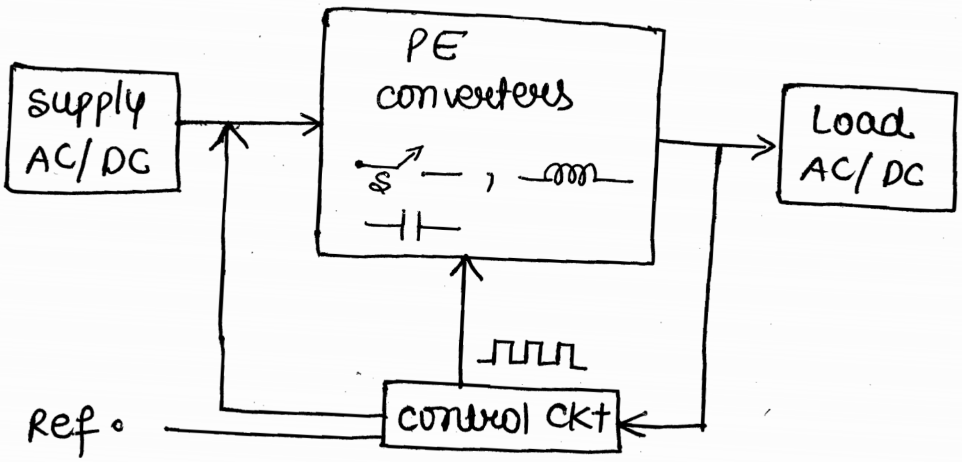
Between the sensitive load & power supply we use power electronic converter so to minimize the voltage fluctuation. Ex-: stablizer to Refrigerator. i.e; conditioning of electrical power



selection of switches depend on → power rating → voltage rating → current rating | freq. rating.

↳ Not used because power dissipation element.

(ON/OFF)
control the switches we need control ckt and it is low power circuit or signal level ckt. Here we can use resistive element.



Power electronic deals with control, conversion and conditioning of electric power using semiconductor devices & these sc devices should operate with high efficiency. In power electronic, semiconductor devices are mainly used as switches.

A —S— K

In this devices there will be two terminal Anode (A) & cathode (K). But some of the devices are also having Gate terminal also.

suppose diode is only having two terminal Anode & cathode not having Gate (G) terminal that's why diode is uncontrolled device.

| Cycloconverter : V_0, f_0 AC ⟶ AC | High power & low speed in drive |

Semiconductor switches :-

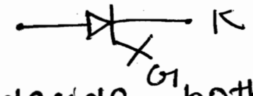
(i) uncontrolled switch : (eg) Diode A —▷|— K , DAIC

In the diode device there is no gate terminal so the ON/OFF state of diode will not decide then **who decide the ON/OFF state of device?** Nature of the ckt will decide it.

(ii) semicontrolled switch : (eg) A —▷|— K (G) , TRAIC

In SCR, the anode & cathode terminal is connected to the supply & load respectively & Gate terminal is only decide the ON state but we can not decide the turn OFF time by using Gate terminal

(iii) Fully controlled switches : (eg) GTO

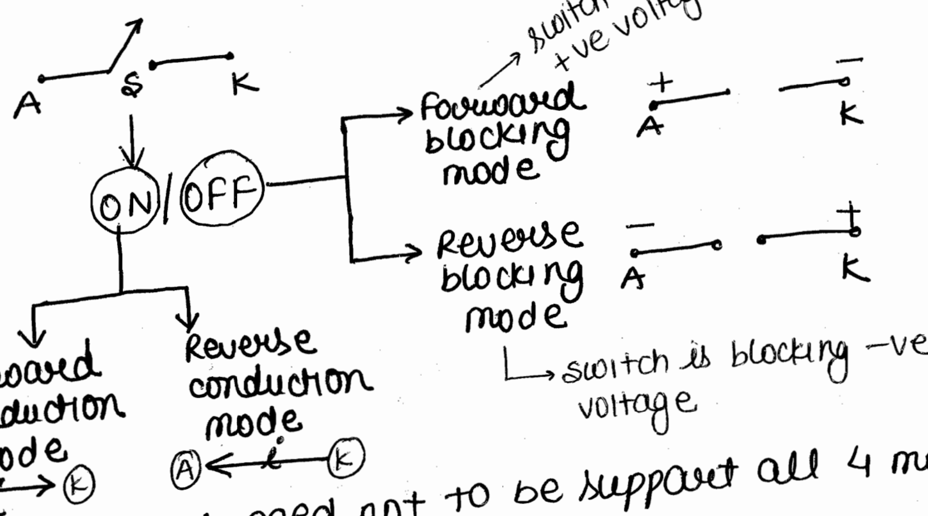


Gate is controlled terminal which decide both ON & OFF state.

when we give $+I_g$ to Gate terminal then GTO ≡ ON

$-I_g$ to Gate terminal then GTO ≡ OFF

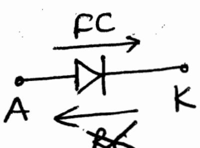
(eg) BJT, MOSFET, IGBT

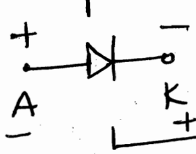


NOTE :-

All the semiconductor devices need not to be support all 4 mode.

Eg :- Diode

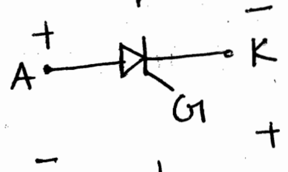




→ we can not block the forward voltage ✗ FB

→ it can block Reverse voltage RB ✓

SCR



→ it can block the forward voltage when Gate terminal is in OFF state

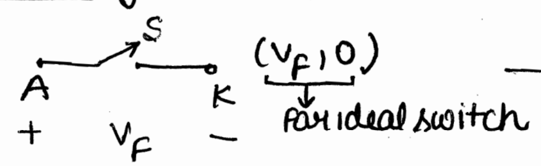
→ it can block the reverse voltage also when Gate = 0 & current direction is only one way.

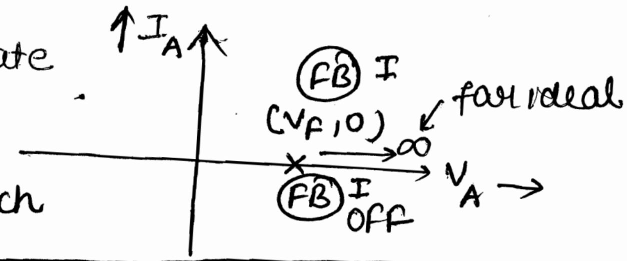
SCR → FB, RB → bipolar blocking capability

Diode	SCR
FC, RB	FB, RB, FC bipolar blocking capability with unidirectional current

Four-mode of an ideal switch :-

(i) Forward blocking mode : i.e, OFF state

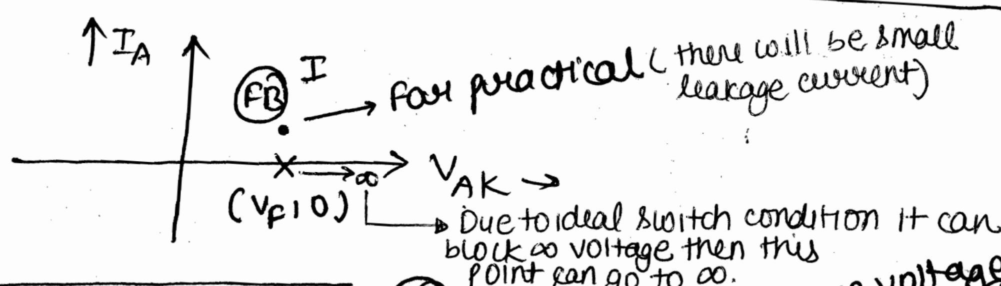




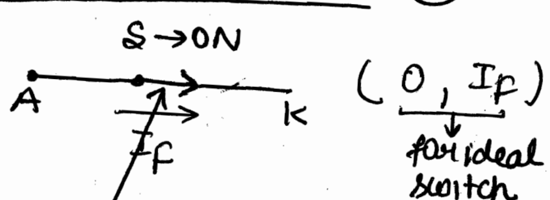
An ideal device when blocking the forward voltage (V_F) then current passing through the device is zero Amp but in practical some leakage current flow through it due to minority current.
Now, we are having some losses in semiconductor device even in the OFF state i.e, blocking power loss = [$V_F \times I_{leakage}$]
If it is ideal switch then it can block ∞ voltage through it.
But practically it is not possible to apply ∞ voltage across it.

> **voltage rating :** that much maximum voltage semiconductor device can block. [withstand in blocking state]

× → ideal
• → practical

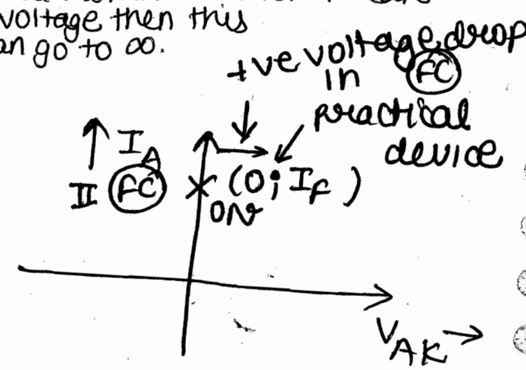


(ii) Forward conduction mode : (FC)



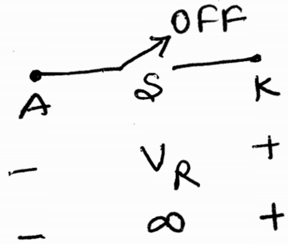
voltage drop in practical case

there will be conduction loss in the device → major loss among all three losses
$= (V\text{-drop}) \times I_F$

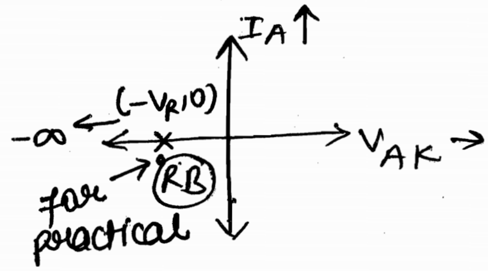


Switching power loss : The variation of current & voltage from (FB) mode to (FC) mode there will be loss in it which is known as switching power loss.
It is depend on the switching frequency of switch (f) if f ↑ then switching power loss ↑

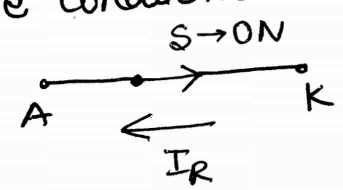
(iii) Reverse blocking mode (RB) :-



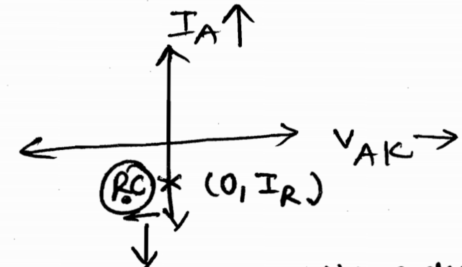
↳ not possible



(iv) Reverse conduction mode (RC)



↳ drop is -ve for practical case



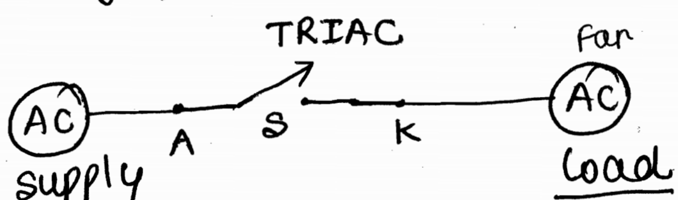
negative voltage drop in (RC)

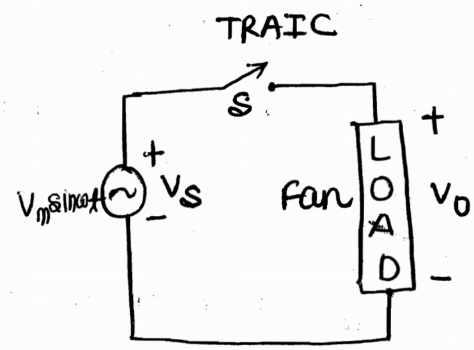
TRAIC supports all the 4 modes

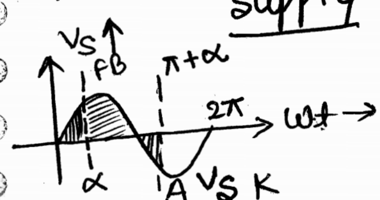
↳ **AC → AC converter**

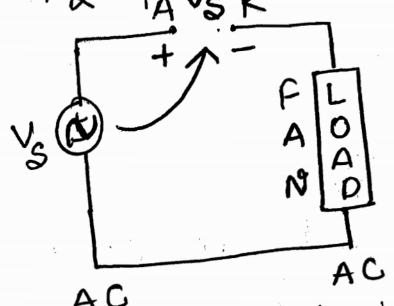
in these converter we use that switch which support all the 4 modes.

(eg) **controlling** the **fan speed** by **regulator** i.e; **controlling** the voltage **V_{ac}** **without** **disturbing the frequency**.





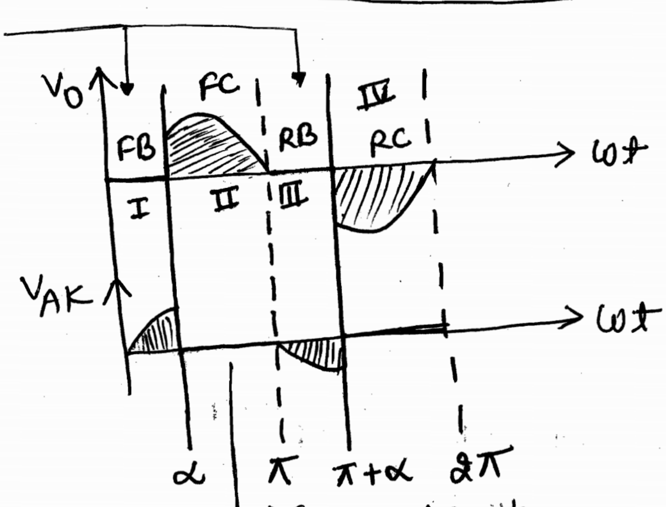




when we are not giving supply to Gate terminal + Then entire voltage appear across the switch. ($V_{AK} = V_S$) & $V_0 = 0$

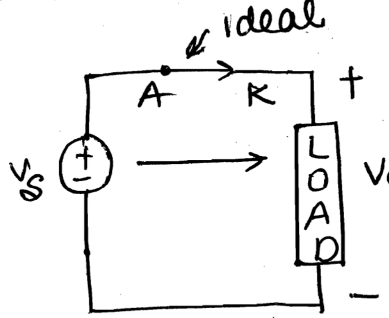
↳ FB [let up to α]

when $I_g = 0$;



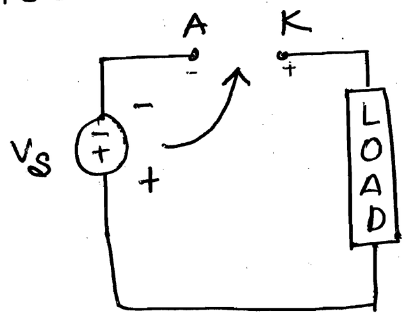
↳ For ideal switch $V_{drop} = V_{AK} = 0$

(II) mode -: Giving Gate signal to the TRIAC then TRIAC will turn ON & conduction in the forward direction

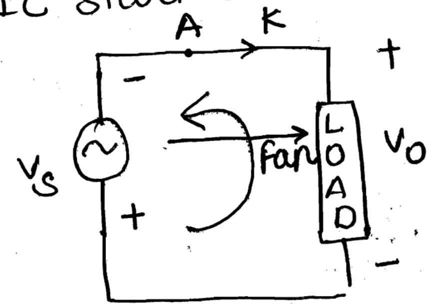


entire supply voltage appears across the load.

(III) mode -: Now the supply voltage is reverse (−ve) again it blocking the reverse voltage because did not give gate signal to TRIAC. Then entire −ve voltage appear across the device.



(IV) mode -: Now, giving −Ig (negative pulse) signal to the TRAIC the TRAIC start conduction in reverse direction



negative voltage appear across the load.

Tell me how do we vary the voltage?

→ AC voltage is measure in the form of RMS voltage value.

how do we control the RMS value.

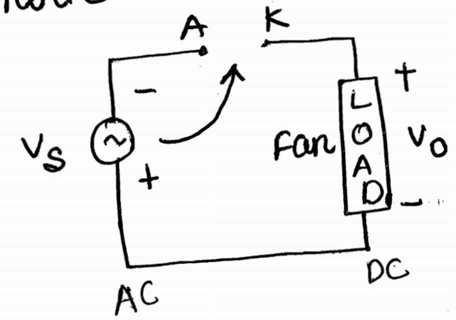
control the both area symmetrically (vograph) to eliminate the dc component. (or) area of both must be equal in order to eliminate the dc component. How much time we block the positive voltage same time we must block negative voltage so that both area should equal. Make sure that in AC side; DC component is always eliminated.

α, V_{RMS} ↗

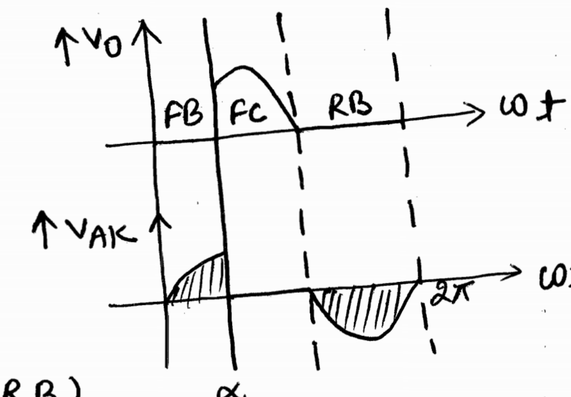
AC → AC, support FB, FC, RB, RC mode TRAIC

Suppose at the place of AC load there is DC load then we have to eliminate the negative voltage V_0 in (IV) mode then we have to use that switch which support only 3 mode which are FB, FC, RB i.e; use SCR

(IV) mode



SCR does not allow (RC).



AC → DC : SCR | FB, FC, RB

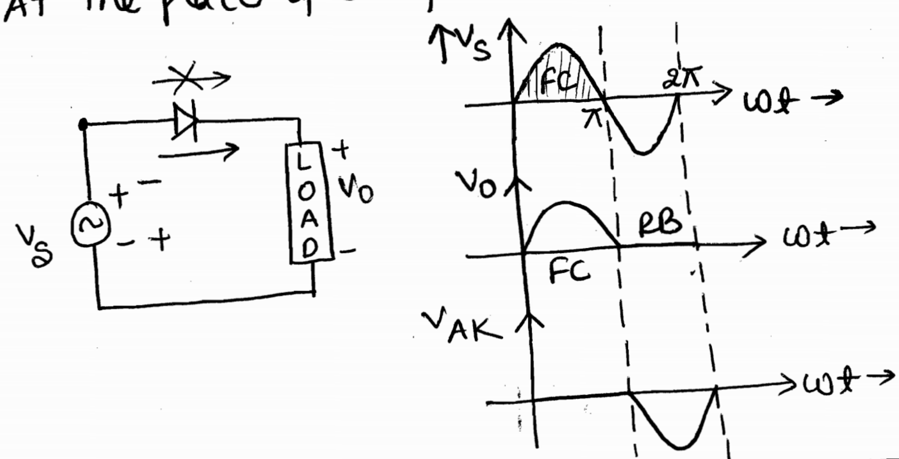
(i) phase controlled Rectifier

| α → V_0 ↗ | (FB, FC, RB)

To measure the DC component we measure the average value by adjusting the firing angle of SCR (α) we can get variable dc voltage. V_0 ↗

At the place of SCR, let me use diode here.

V_0 → constant here

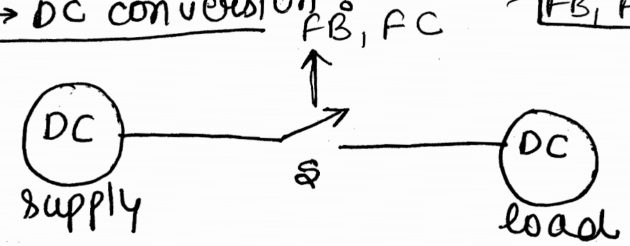


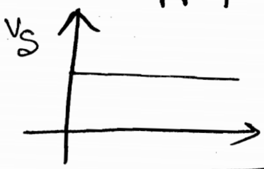
(ii) uncontrolled Rectifiers (Diodes) → FC, RB | V_0 → constant

we can not vary the average voltage

iii) **DC → DC conversion**: → **FB, FC mode**

eg: All power transistor BJT, MOSFET, IGBT





~~RB, RC~~

Here we **don't have negative voltage** here then **working of switch** only **block the forward voltage** & **forward conduction**. At very high power level where we don't have any choice (BJT, MOSFET, IGBT) then we use SCR (FB, FC, RB) but in DC → DC conversion only two modes (FB, FC) then RB is extra here & nothing will happen. **GTO, SCR** → high power application

power transistor is used for high ~~power~~ freque application.
SCR is used for high power application.

iv) **DC → AC (inverters)**

voltage const^n: capa^{ci}
current const^n: inductor

Inverters

- VSI
  - $P = V I$: (+)(+) → FC; (−)(−) → RC; FB
  - (FB, FC, RC) → Requirement of switch
  - eg: **RCT** Reverse conduction Thyristor
- CSI
  - $P = V I$: FB, RB, FC
  - (FB, FC, RB) → Requirement of switch
  - eg: **SCR**

CSI → SCR; VSI → RCT

Diode	SCR	TRAIC	RCT
FC RB	FC FB RB	FB FC RB RC	FB FC RC
	AC → DC	AC → AC	DC → AC

1. Phase controlled Rectifier	2. uncontrolled Rectifier
AC → DC SCR AC → AC TRAIC	Diode
3. DC → DC	4. AC → AC
FB, FC	VSI / CSI RCT / SCR