Study Notes on Commutation Techniques of Thyristor & Diode Circuit Rectifiers

Here you will find the study notes on Thyristor Commutation Techniques & Diode Circuit Rectifiers which will cover the topics such as Thyristor, V-I Characteristic of Natural Commutation Circuit, Forced Commutation, Different Types Classes of Forced Commutation, Diode Circuit Rectifier, Half-Wave Bridge Rectifier & Full Wave Bridge Rectifier.

Thyristor Commutation Techniques

Because The continuous conduction of thyristors causes problems in some applications. The process used for turning off a thyristor is called commutation. By the commutation process, the thyristor operating mode is changed from forward conducting mode to forward blocking mode. So, the thyristor commutation methods of thyristor commutation techniques are used to turn off.

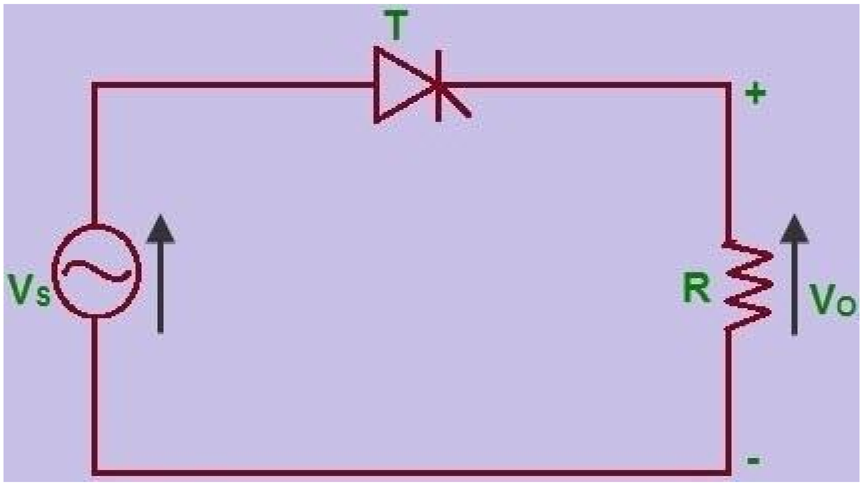
- Most of the Converter Equipments and Switch-Mode Power Supplies (SMPS) use power electronics components like thyristors, MOSFET and other power semiconductor devices for high frequency switching operations at high-power ratings.
- Here we are considering the thyristors that we use very frequently as bistable switches in several applications. These thyristors use switches needed to be switched on and off. For switching ON the thyristors, there are some Thyristor Turn ON methods called as thyristor triggering methods. Similarly, for Switching Off Thyristors, there are methods called as thyristors commutation techniques.

The commutation techniques of thyristors are classified into two types:

- Natural Commutation
- Forced Commutation

Natural Commutation

Generally, if we consider AC supply, the current will flow through the zero crossing line while going from positive peak to negative peak. Thus, a reverse voltage will appear across the device simultaneously, which will turn off the thyristor immediately. This process is called as natural commutation as thyristor is turned off naturally without using any external components or circuit or supply for commutation purposes.



- Natural commutation can be observed in AC voltage controllers, phase controlled rectifiers and Cycloconverters.

Forced Commutation

- The thyristor can be turned off by reverse biasing the SCR or by using active or passive components. Thyristor current can be reduced to a value below the value of holding current. Since the thyristor is turned off forcibly it is termed as a forced commutation process.

- Forced commutation can be observed while using DC supply; hence it is also called as DC commutation. The external circuit used for the forced commutation process is called a commutation circuit and the elements used in this circuit are called commutating elements.

Classification of Forced Commutation Methods

The forced commutation can be classified into different methods as follows:

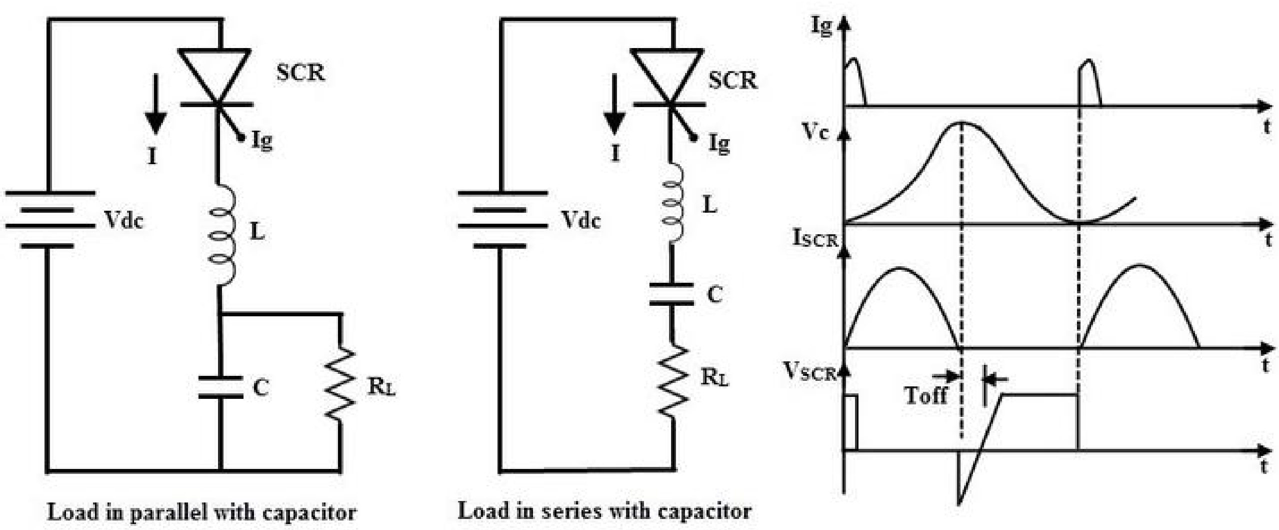
- **Class A**: Self commutated by a resonating load
- **Class B**: Self commutated by an LC circuit
- **Class C**: Cor L-C switched by another load carrying SCR
- **Class D**: C or L-C switched by an auxiliary SCR

- **Class E**: An external pulse source for commutation
- **Class F**: AC line commutation

Class A: Self Commutated by a Resonating Load

This is also known as self commutation, or resonant commutation, or load commutation. In this commutation, the source of commutation voltage is in the load. This load must be an under-damped R-L-C supplied with a DC supply so that natural zero is obtained.The commutating components L and C are connected either parallel or series with the load resistance R as shown below with waveforms of SCR current, voltage and capacitor voltage.

- Class A is one of frequently used thyristor commutation techniques. If the thyristor is triggered or turned on, then anode current will flow by charging **Capacitor C** with a dot as positive.
- The second order under-damped circuit is formed by the **Inductor or AC Register, Capacitor and Resistor**. If the current builds up through SCR and completes the half cycle, then the inductor current will flow through the SCR in the reverse direction which will turn off the thyristor.

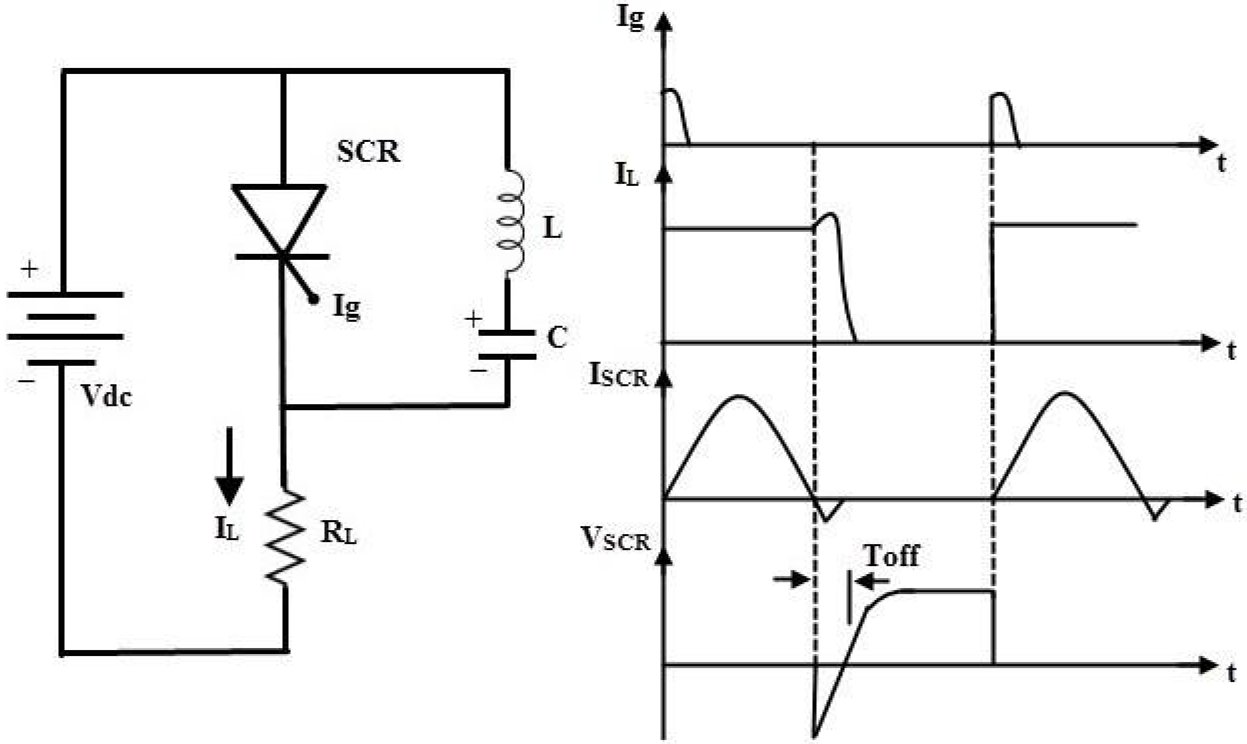


- After the thyristor commutes or turns off the thyristor, the capacitor will start discharging from its peak value through the resistor in an exponential manner. The thyristor will be in reverse bias condition until the capacitor voltage returns to the supply voltage level.

- The value of load resistance and commutating components are so selected that they form an under-damped resonant circuit to produce natural zero. When the thyristor or SCR is triggered, the forward current starts flowing through it and during this, the capacitor is charged up to the value of E.
- Once the capacitor is fully charged (more than the supply source voltage) the SCR becomes reverse biased and hence the commutation of the device.
- The capacitor discharges through the load resistance to make ready the circuit for the next cycle of operation. The time for switching OFF the SCR depends on the resonant frequency which further depends on the L and C components.

Class B: Self Commutated by an L-C Circuit

- The major difference between the class A and class B thyristor commutation techniques is that the LC is connected in series with thyristor in class A, whereas in parallel with thyristor in class B.
- Before triggering on the SCR, the capacitor is charged up (dot indicates positive). If the SCR is triggered or given a triggering pulse, then the resulting current has two components.
- The constant load current flowing through the R-L load is ensured by the large reactance connected in series with the load which is clamped with freewheeling diodes.
- If sinusoidal current flows through the resonant L-C circuit, then the capacitor C is charged up with a dot as negative at the end of the half cycle.



- When the DC supply is applied to the circuit, the capacitor charges with an upper plate positive and lower plate negative up to the supply voltage E. When the SCR is triggered, the current flows in two directions, one is through **E+–SCR–R–E-** and another one is the commutating current through L and C components.

- Once the SCR is turned ON, the capacitor starts discharging through **C+–L–T–C-**. When the capacitor is fully discharged, it starts charging with a reverse polarity. Hence a reverse voltage applied across the SCR which causes the commutating current IC to oppose load current IL.

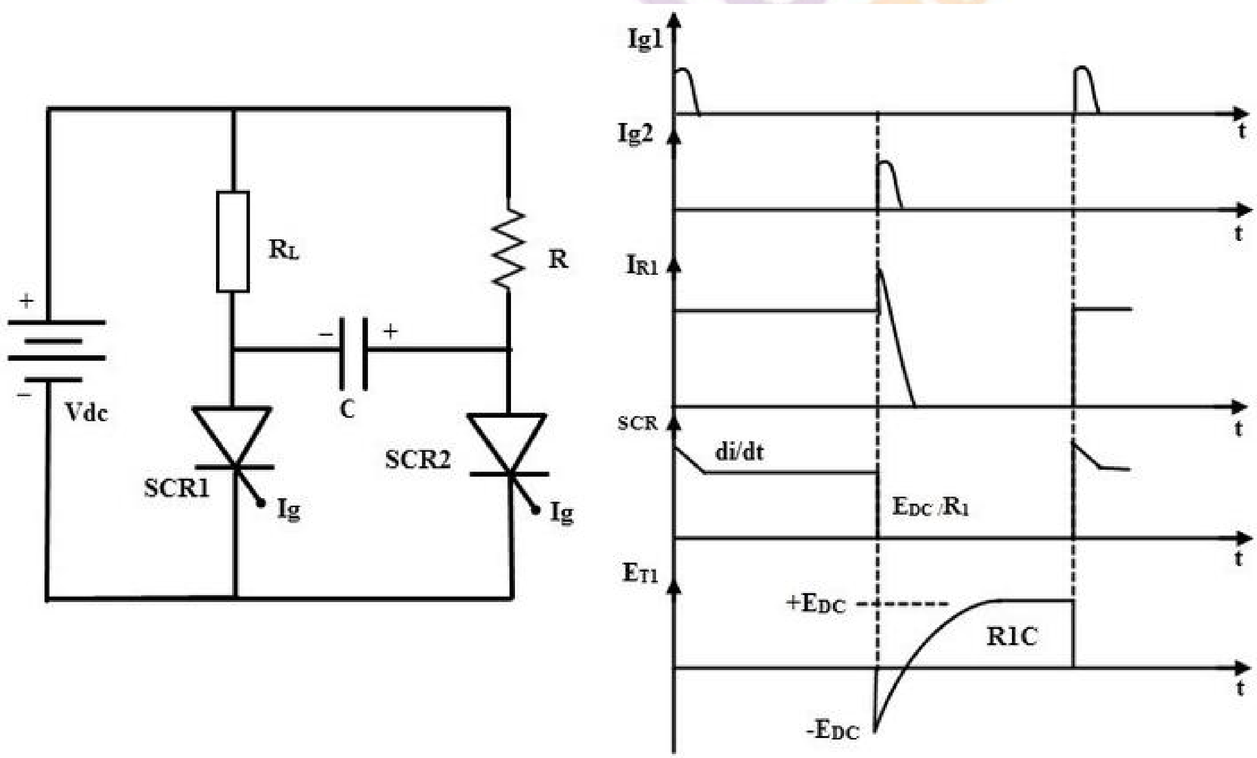
- When the commutating current Ic is higher than the load current, the SCR will automatically turn OFF and the capacitor charges with original polarity.

- In the above process, the SCR is turned ON for some time and then automatically turned OFF for some time. This is a continuous process and the desired frequency of ON/OFF depends on the values of L and C. This type of commutation is mostly used in chopper circuits.

Class C: C or L-C Switched by another Load Carrying SCR

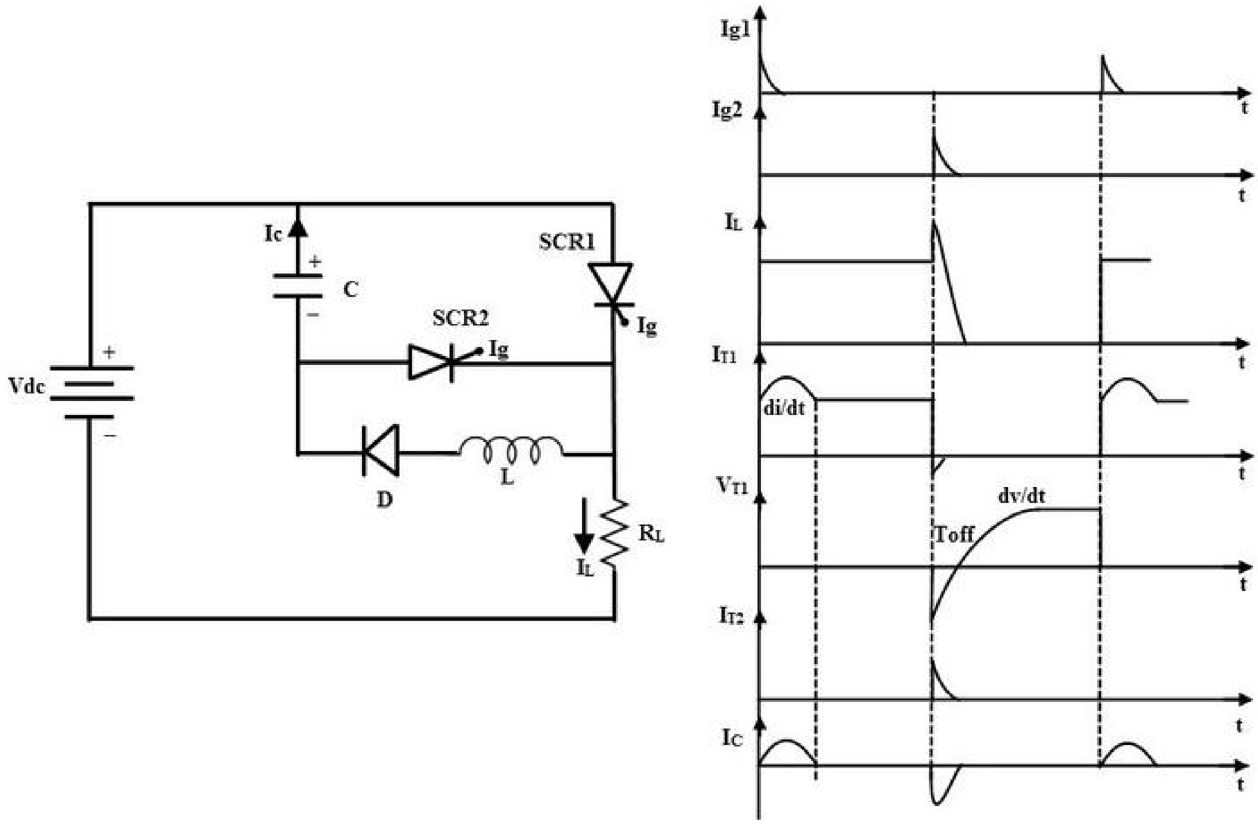
In the above thyristor commutation techniques we observed only one SCR but in these class C commutation techniques of thyristor there will be two SCRs. One SCR is considered as a main thyristor and the other as an auxiliary thyristor. In this classification, both may act as main SCRs carrying load current and they can be designed with four SCRs with load across the capacitor by using a current source for supplying an integral converter.

- In this commutation method, the main SCR to be commutated is connected in series with the load and an additional or complementary SCR is connected in parallel with main SCR. This method is also called complementary commutation.
- If the thyristor T2 is triggered, then the capacitor will be charged up. If the thyristor T1 is triggered, then the capacitor will discharge and this discharge current of C will oppose the flow of load current in T2 as the capacitor is switched across T2 via T1.



Class D: L-C or C Switched by an Auxiliary SCR

The class C and class D thyristor commutation techniques can be differentiated with the load current in class D: Only one of the SCR's will carry the load current while the other acts as an auxiliary thyristor whereas in class C both SCRs will carry load current. The auxiliary thyristor consists of a resistor in its anode which is having resistance of approximately ten times the load resistance.



- When the supply voltage E is applied, both SCRs are in OFF state and hence the capacitor voltage is zero. In order to charge the capacitor, SCR2 must be triggered first. So the capacitor charges through the path **E+–C+–C–SCR2- R- E-**.

- When the capacitor is fully charged the SCR2 becomes turned OFF because no current flows through the SCR2 when the capacitor is charged fully. If the SCR1 is triggered, the current flows in two directions; one is the load current path **E+ – SCR1- R- E-** and another one is the commutation current path **C+ – SCR1- L- D- C**.

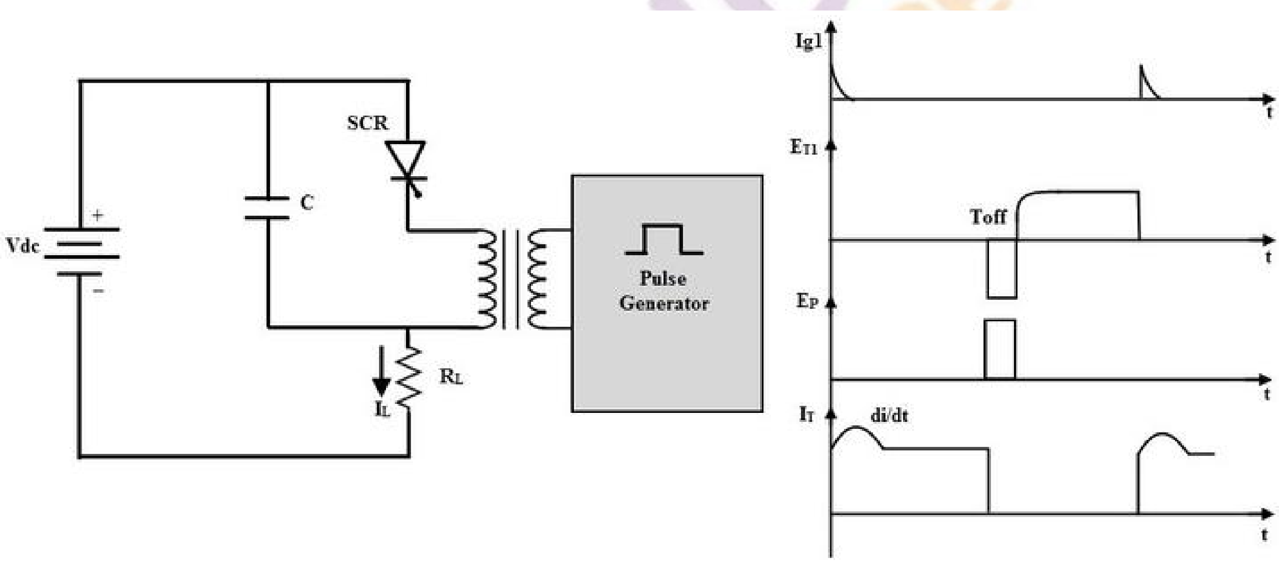
- As soon as the capacitor completely discharges, its polarities will be reversed but due to the presence of diodes, the reverse discharge is not possible. When the SCR2 is triggered, the capacitor starts discharging through **C+ – SCR2- SCR1- C-**.

- When this discharging current is more than the load current the SCR1 becomes turned OFF.Again, the capacitor starts charging through the SCR2 to a supply voltage E and then the SCR2 is turned OFF.

- Therefore, both SCRs are turned OFF and the above cyclic process is repeated. This commutation method is mainly used in inverters and also used in the Jones chopper circuit.

Class E: External Pulse Source for Commutation

- For the class E thyristor commutation techniques, a transformer which can not saturate (as it is having a sufficient iron and air gap) and capable of carrying the load current with small voltage drop compared with the supply voltage.
- If the thyristor T is triggered, then the current will flow through the load and pulse transformer.This is also known as external pulse commutation. In this, an external pulse source is used to produce the reverse voltage across the SCR.
- The circuit below shows the class E commutation circuit which uses a pulse transformer to produce the commutating pulse and is designed with tight coupling between the primary and secondary with a small air gap.

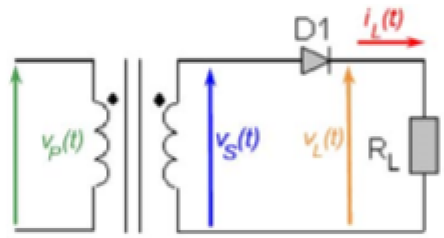


Diode Circuit Rectifier

- Since the currents in the magnets have either to be varied according to the energy (or the required changes in the orbit) of the particles or at least have to be ramped from the turn on values to their final values.
- The rectifiers use thyristor-based structures or mixed ones (diodes and thyristors or diodes/thyristors and transistors).
- The effects on the rectifier behavior of the inductive components of the load and of the AC line will be investigated. The use of passive filters to reduce the harmonic content (ripple) of the voltage and current at the output of the rectifier will be discussed.

Single Phase Half-wave rectifier

This is the simplest structure. Only one diode is placed at the secondary of the transformer. From the figure, the waveforms of the voltage at the secondary and of the current in the load are shown. Since the load is a resistance, the voltage on the load is proportional to the current.



- It is quite evident why this type of rectifier is called half-wave: the rectification process occurs only during half-periods. It is also called single-way because the load current iL(t) always circulates in the secondary winding in the same direction.

$$V_{DC} = \frac{1}{T}\int_0^T v_L(t)dt = \frac{1}{2\pi}\int_0^\pi V_S \sin(\varpi t)dt = \frac{V_S}{\pi}$$

$$V_L = \sqrt{\frac{1}{T}\int_0^T v_L^2(t)dt} = \sqrt{\frac{1}{2\pi}\int_0^\pi V_S^2 \sin^2(\varpi t)dt} = \frac{V_S}{2}$$

$I_{dc} = V_{dc}/R_L$

$I_L = V_L/R_L$

The current in the secondary of the transformer can flow only when the diode conducts and therefore it is equal to the current in the load:

$FF = V_L/V_{DC} = \pi/2$

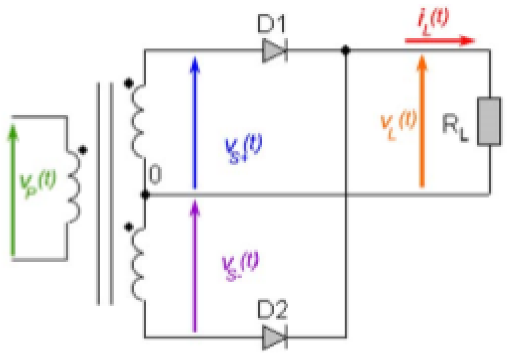
$$\eta = \left(\frac{1}{FF}\right)^2 = \frac{4}{\pi^2} = 0.405$$

$$RF = \sqrt{FF^2 - 1} = 1.21$$

TUF = 0.323 (or 0.286 TUF = according to some authors).

Full-wave rectifier — centre-tapped

In order to use both halves of the secondary AC voltage waveform, one can use two diodes and create a return path for the current by adding a tap at the centre of the secondary winding. This is the so-called centre-tapped rectifier.



- Diode D1 conducts during the positive half-wave of the voltage. Diode D2 conducts in the negative half. The current always flows from the common point of the diodes, through the load and back to the central tap of the transformer.

Using the definitions reported in the previous section and the symmetries, we get the following results

$$V_{DC} = \frac{1}{T}\int_0^T v_L(t)dt = \frac{2}{2\pi}\int_0^\pi V_S \sin(\varpi t)dt = \frac{2\cdot V_S}{\pi}$$

$I_{DC} = V_{DC}/R_L$

$= 2.V_S/\pi R_L$

$I_L = V_L/R_L = V_S/\sqrt{2}\, R_L$

$FF = V_L/V_{DC} = \pi/2\sqrt{2} = 1.11$

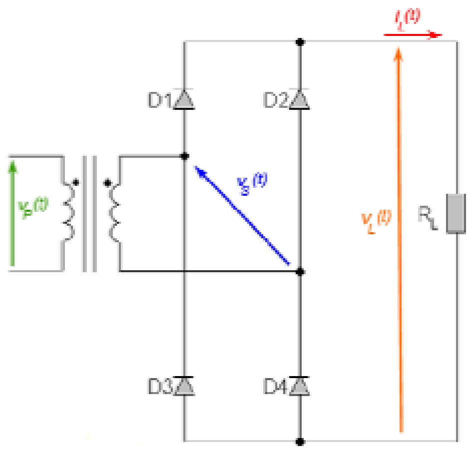
$\eta = (1/FF)^2 = 0.81$

$$RF = \sqrt{FF^2 - 1} = 0.483$$

TUF = 0.671 (or 0.572 TUF = according to some authors).

Full-wave rectifier — bridge

The bridge structure is the best single-phase rectifier. At the cost of two more diodes, several advantages are obtained. This is a full-wave rectifier but compared with the centre-tapped solution it uses a simpler transformer, with a single secondary and no additional taps.



- The rectification takes place by the conduction of couples of diodes. Diodes D1 and D4 are conducting during the positive half-wave of the voltage. Diode D2 and D3 are conducting during the negative half. This is a double-way topology.
- In each half-cycle, the current flows in both directions in the secondary winding but always in the same direction in the load. There is no DC component in the winding and the core can be smaller than that for a centre-tapped rectifier with the same DC power rating.

$$TUF = \frac{V_{DC} \cdot I_{DC}}{\frac{V_S}{\sqrt{2}} \cdot \frac{I_S}{\sqrt{2}}} = 0.813$$

Thanks!

BYJU'S Exam Prep - The Most Comprehensive App!