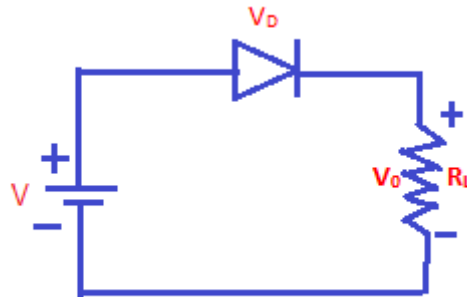# Load Line of Diode Circuit

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Half wave Rectifier

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LOAD LINE OF A DIODE CIRCUIT

Diode Circuit

Diode characteristics with load line

$$V = V_D + V_0$$
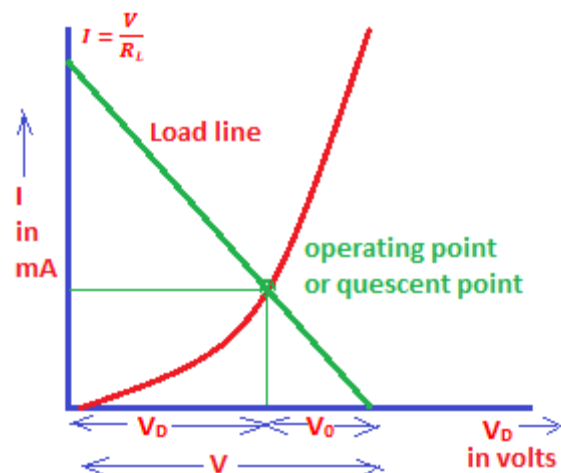$$= V_D + IR_L$$

When $I = 0$, then $V = V_D$

This gives a point $(V_D, 0)$ on the horizontal axis.

when $V_D = 0$, then $I = \dfrac{V}{R_L}$

This gives another point $(0, \dfrac{V}{R_L})$ on vertical axis.

A line passing through these two points gives all possible combinations of I and V_D that satisfy the above equation.

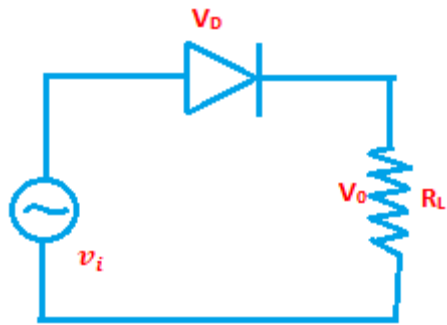The intersection of load line with static characteristic curve provides a point known as quiescent point or operating point.

The above equation can be written as

$$I = \frac{V}{R_L} - \frac{V_D}{R_L} => I = -\frac{1}{R_L}V_D + \frac{V}{R_L}$$

This gives the equation of a straight line with slope $-\dfrac{1}{R_L}$ and the load line intercept the current axis at $\dfrac{V}{R_L}$.
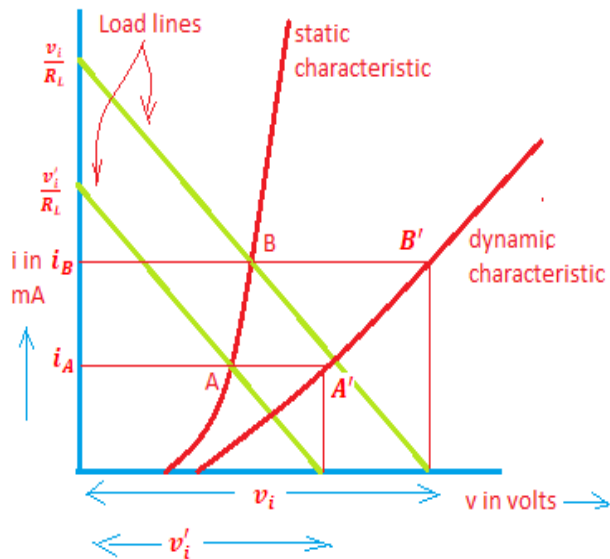
AC APPLIED VOLTAGE(DYNAMIC CHARACTERISTIC)

This is the basic diode circuit in which the input voltage is a variable quantity.

For a convenient interval of instantaneous voltage , we draw different load lines. It is obvious from the graph that the load lines are parallel to each other.

The intersection of different load lines with static curve of diode will give the current in the circuit corresponding to each value of input voltage.

With the help of these currents, the output current waveform may be considered.

RECTIFIER

A rectifier is an electronic device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in one direction.

The process is known as rectification, since it 'straightens 'the direction of current.

Rectifiers has many uses, but are often found serving as components of <u>DC power supply</u> and <u>high voltage direct current(HVDC)</u> power transmission system.

Rectification may serve in roles other than to generate direct current for use as a source of power . Detectors of radio signals serves as rectifier.

Depending on the type of alternating current supply and the arrangement of the rectifier circuit, the o/p voltage may require additional smoothing to produce a uniform steady voltage.

Much more complex circuitry that performs the opposite function, that is converting DC to AC is called an <u>inverter.</u>

For power rectification from very low to very high current, semicoductor diodes of various types (junction diodes, Schottky diodes, etc) are widely used.

Rectifier circuits may be single phase or multiphase. Most low power rectifiers for domestic equipments are single phase, but three phase rectification is very important for industrial application and for the transmission of energy as DC (HVDC).

SINGLE PHASE RECTIFIER
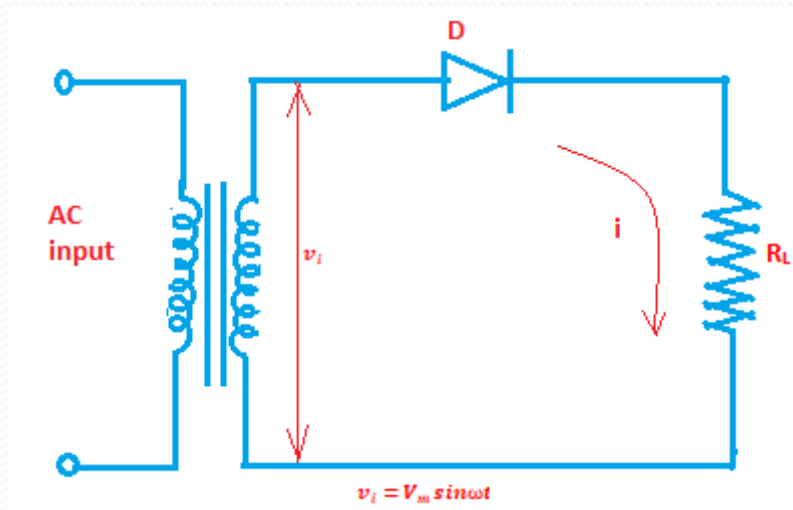
$v_i = V_m \sin \omega t$

Let $v_i = V_m \sin \omega t$
Current through the load resistance
$$i = I_m \sin \omega t \qquad \text{for } 0 \leq \omega t \leq \pi$$
$$= 0 \qquad\qquad \text{for } \pi \leq \omega t \leq 2\pi$$

and peak current

$$I_m = \frac{V_m}{R_f + R_L} \quad , \quad R_f = \text{dynamic resistance}$$
of the diode

$$I_{dc} = \frac{1}{2\pi} \int_0^{2\pi} i\, d(\omega t)$$

$$= \frac{1}{2\pi} \int_0^{\pi} I_m \sin\omega t \, d(\omega t) + \frac{1}{2\pi} \int_{\pi}^{2\pi} 0 \, d(\omega t)$$
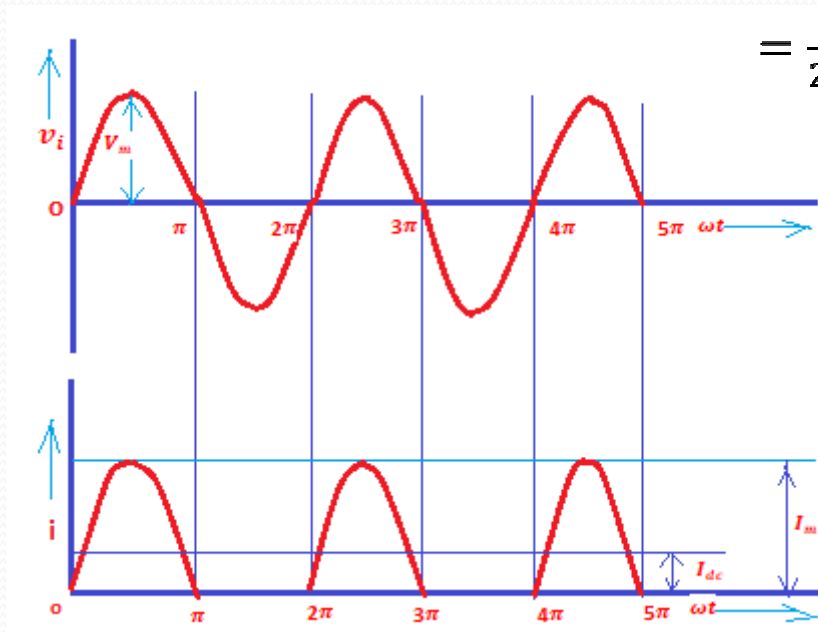
$$= \frac{I_m}{2\pi} [-\cos\omega t]_0^{\pi}$$

$$= \frac{I_m}{\pi}$$

$$= \frac{V_m}{\pi(R_L + R_f)}$$

Therefore, the dc voltage

$$V_{dc} = I_{dc} R_L = \frac{I_m R_L}{\pi}$$

$$= \frac{V_m R_L}{\pi(R_L + R_f)} = \frac{V_m}{\pi(1 + \frac{R_f}{R_L})}$$

The root mean square value of load current

$$I_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i^2 d(\omega t)}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{\pi} I_m^2 sin^2(\omega t) d(\omega t)}$$

$$= \frac{I_m}{2} = \frac{V_m}{2(R_f + R_L)}$$

$$V_{rms} = I_{rms} R_L = \frac{V_m}{2(1 + {}^{R_f}/_{R_L})}$$

RECTIFIER EFFICIENCY

It is defined as the ratio of the dc o/p power to the ac i/p power

$$\eta = \frac{dc\ power\ delivered\ to\ the\ load, P_{dc}}{ac\ input\ power\ from\ transformer\ secondary, P_{ac}}$$

$$P_{ac} = I_{rms}^2 (R_f + R_L)$$

$$= \left(\frac{I_m}{2}\right)^2 (R_f + R_L)$$

$$P_{dc} = I_{dc}^2 R_L$$

$$= \frac{I_m^2 R_L}{\pi^2}$$

$$\eta = \frac{I_m^2 R_L / \pi^2}{I_m^2 (R_f + R_L)/4} = \frac{4}{\pi^2} \left(\frac{R_L}{R_f + R_L}\right) = \frac{40.6}{1 + \frac{R_f}{R_L}}$$

RIPPLE FACTOR

$$i = \frac{I_m}{\pi} + \frac{I_m}{2} \sin\omega t - \frac{2I_m}{3\pi} \cos 2\omega t - \frac{2I_m}{15\pi} \cos 4\omega t + \dots$$

$$= I_{dc} + I_r$$

$$\gamma = \frac{I'_{rms}}{I_{dc}}$$

$$I^2_{rms} = I^2_{dc} + I'^2_{rms}$$

$$\gamma = \frac{\left(I^2_{rms} - I^2_{dc}\right)^{1/2}}{I_{dc}}$$

$$= \left[\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1\right]^{1/2}$$

$$= \left[\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1\right]^{1/2}$$

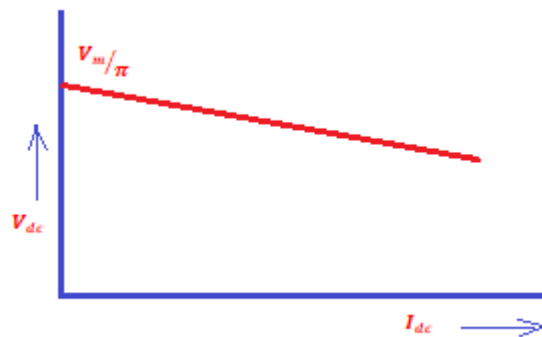$$= \sqrt{\frac{\pi^2}{4} - 1} = 1.21$$

REGULATION

$$I_{dc} = \frac{V_m}{\pi(R_L + R_f)}$$

$$I_{dc}R_L = \frac{V_m}{\pi} - I_{dc}R_f$$

$$V_{dc} = \frac{V_m}{\pi} - I_{dc}R_f$$

When $I_{dc} = 0$, V_{dc} has its maximum value. This equation suggests that a half wave rectifier functions as if it were a constant voltage source in series with an internal resistance R_f. Thus V_{dc} is equal to V_m/π with no load and dc output decreases linearly with the increase of dc output current.

Percentage regulation

$$S_L = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

Where V_{NL} is the voltage at no load and V_{FL} is the voltage at full load

If V_{NL} equals to V_{FL} , this results as there is no voltage drop and the value of S_L becomes zero.

For an ideal power supply, the percentage of regulation should be zero i.e. the output voltage should be independent of load current.

PEAK INVERSE VOLTAGE(PIV)

The maximum reverse voltage across the diode is called the peak inverse voltage(PIV) of the rectifier. In a half wave rectifier, without filter, the peak inverse voltage across the diode is the maximum transformer voltage across the secondary. Thus, here

$$PIV = V_m$$

In no case PIV should exceed this rated maximum reverse voltage.

TRANSFORMER UTILIZATION FACTOR(TUF)

$$TUF = \frac{dc\ power\ delivered\ to\ the\ load}{ac\ rating\ of\ the\ transformer\ secondary}$$

$$= \frac{P_{dc}}{P_{ac}(rated)}$$

$$= \frac{I_{dc}^2 R_L}{\frac{V_m I_m}{\sqrt{2}\ 2}} = \frac{(\frac{I_m}{\pi})^2 R_L}{\frac{V_m I_m}{2\sqrt{2}}} = \frac{2\sqrt{2}}{\pi^2} \frac{I_m}{V_m} R_L$$

But

$$V_m = I_m(R_f + R_L)$$

$$TUF = \frac{2\sqrt{2}}{\pi^2}\left(\frac{R_L}{R_L+R_f}\right)$$

$$= 0.286\left(\frac{1}{1+{R_f}/{R_L}}\right)$$

When $R_L \gg R_f$, then TUF= 0.286

For example, when 1 kVA transformer is used in half wave rectifying circuit, the dc power that can be delivered to a resistive load by this transformer without overheating will be $1 \times 0.286 = 0.286\ KW\ or\ 286\ Watts.$

RELATIONSHIP BETWEEN EFFICIENCY AND TUF

$$TUF = = \frac{P_{dc}}{P_{ac}(rated)} = \frac{P_{dc}}{P_{ac}} \frac{P_{ac}}{P_{ac}(rated)} = \eta \frac{P_{ac}}{P_{ac}(rated)}$$

$$P_{ac} = I_{rms}^2 (R_f + R_L) = \frac{I_m^2}{4}(R_f + R_L)$$

$$P_{ac}(rated) = \frac{V_m}{\sqrt{2}} \frac{I_m}{2} = \frac{I_m(R_f + R_L)}{\sqrt{2}} \frac{I_m}{2} = \frac{I_m^2}{2\sqrt{2}}(R_f + R_L)$$

$$\frac{P_{ac}}{P_{ac}(rated)} = \frac{I_m^2(R_f + R_L)/4}{I_m^2(R_f + R_L)/2\sqrt{2}} = \frac{2\sqrt{2}}{4} = \frac{1}{\sqrt{2}} = 0.707$$

This gives

$$TUF = \eta \times 0.707 = 28.7042$$