RECTIFIERS
and
VOLTAGE REGULATION
(2)

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Full Wave Rectifier

While discussing half wave rectifier we have noted that it suffers from many disadvantages:

1. There is excessive ripple
2. Low efficiency
3. D.C. saturation of transformer secondary coil

We will develop this rectifier into a full wave rectifier by addition of another diode.
The secondary of the transformer is center-tapped and as such it has twice the voltage from line to line when AC voltage is applied across the primary coil of the transformer.
During positive half of input voltage the upper terminal A is positive the diode $D_1$ conducts and current flows through $R_L$. The upper end P of load $R_L$ is positive. Path of current is $AD_1PQC$.

The $D_2$ does not conduct since the lower terminal B is negative.

During negative half of input voltage the lower end B is positive so the diode $D_2$ conducts and current flows through $R_L$. The upper end P of $R_L$ is positive. Path of current is $BD_2PQC$. 
The DC or average current $I_{dc}$ is given by

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

Each diode operates independently and under exactly the same conditions as in half wave circuit, only the load current are combined.

$$I_{dc} = \frac{1}{2\pi} \left[ \int_0^\pi \frac{E_m}{R_L} \sin \omega td(\omega t) + \int_\pi^{2\pi} -\frac{E_m}{R_L} \sin \omega td(\omega t) \right]$$
The current of $I_m$

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

By substituting for $i$

$$E_m = I_{dc} \times R_L = \frac{2I_m R_L}{\pi} = \frac{2E_m}{\pi}$$

So the output DC voltage

$$I_{dc} = \frac{2E_m}{\pi R_L} = \frac{2I_m}{\pi}$$
We can conclude that for a full rectifier the DC output voltage is

\[ I_{dc} = \frac{2I_m}{\pi} \]

and

\[ V_{dc} = I_{dc} R_L \]

so

\[ V_{dc} = \frac{2V_m}{\pi} - I_{dc} (R_s + R_f) \]

with

\[ I_{rms} = \frac{I_m}{\sqrt{2}} \]
Efficiency of Rectifier

\[ P_{ac} = (I_{rms})^2 (r_f + R_L) = \left( \frac{I_m}{\sqrt{2}} \right)^2 (r_f + R_L) \]

\[ P_{dc} = I_{dc}^2 R_L = \left( \frac{2I_m}{\pi} \right)^2 R_L \]

\[ \eta = \frac{P_{dc}}{P_{ac}} = \frac{\left[ 4I_m^2 / \pi^2 \right] R_L}{\left( I_m^2 / 2 \right) (r_f + R_L)} = \frac{8}{\pi^2} \left[ \frac{1}{(r_f / R_L) + 1} \right] \]

\[ = \frac{8}{\pi^2} = 0,812 = 81,2\% \]
Ripple Factor

Ripple factor \( r \) is defined as the ratio of two current (or voltage) components.

\[
r = \frac{(I_r)_{rms}}{I_{dc}} = \frac{(V_r)_{rms}}{V_{dc}}
\]
Substituting for $I_{\text{rms}}$ and $I_{\text{dc}}$ we have

$$r = \sqrt{\left( \frac{I_m}{I_{\text{dc}}} \right)^2} - 1 = \sqrt{\left( \frac{I_m}{\sqrt{2} I_{\text{dc}}} \right)^2} - 1 = \sqrt{\left( \frac{\pi}{2} \right)^2} - 1 = \frac{\pi^2}{8} - 1 = 0.48$$
Voltage Regulation

The degree to which a power supply varies in output voltage under conditions of load variations is measured by the voltage regulation which is usually expressed as percentage

\[
\%V_r = \left[\frac{V_{\text{noload}} - V_{\text{fullload}}}{V_{\text{fullload}}}\right] \times 100\%
\]
Ratio of Rectification

It is used as measure of merit to compare rectifiers

\[ RoF = \frac{dc \_ power \_ delivered \_ to \_ the \_ load}{ac \_ input \_ power \_ from \_ transformer \_ secondary} \]

\[ RoF = \frac{P_{dc}}{P_{ac}} \]
Transformer Utilization Factor (TUF)

\[
TUF = \frac{P_{dc}}{P_{ac\_rated}} = \frac{\left(\frac{2I_m}{\pi}\right)^2 R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}}
\]

\[
V_m = I_m \left( R_f + R_L \right)
\]
The Bridge Rectifier
For a Bridge rectifier the DC output voltage is

\[ I_{dc} = \frac{2I_m}{\pi} \]

and

\[ V_{dc} = I_{dc} R_L \]

so

\[ V_{dc} = \frac{2V_m}{\pi} - I_{dc} \left(R_s + 2R_f\right) \]

with

\[ I_{rms} = \frac{I_m}{\sqrt{2}} \]
The current of $I_m$

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

By substituting for $i$

$$E_m = I_{dc} x R_L = \frac{2I_m R_L}{\pi} = \frac{2E_m}{\pi}$$

So the output DC voltage

$$I_{dc} = \frac{2E_m}{\pi R_L} = \frac{2I_m}{\pi}$$
The R-C Filter or Shunt Capacitor filter
Charging-discharging of the Condenser Filter
The average value of load current $I_{dc}$ is the average value of the capacitor discharge current over an interval of $T_2$ from $\theta_2$ to $\theta_1$.

The amount of charge lost by the capacitor

\[ Q_{\text{discharge}} = I_{dc} x T_2 \]
This charge is replenished during short interval $T_1$ (from $\theta_1$ to $\theta_2$) during which voltage across capacitor changes by an amount (peak to peak voltage of the ripple)$V_{rpp}$

\[
Q_{ch \arg e} = V_{rpp} xC
\]

\[
Q_{ch \arg e} = Q_{disch \arg e}
\]

\[
V_{rpp} xC = I_{dc} xT_2
\]

\[
V_{rpp} = \frac{I_{dc}}{C} T_2
\]

\[
V_{rpp} = \frac{I_{dc}}{C} x \frac{1}{2f}
\]