I. Transformer utilization Factor (T.U.F):-

- TUF indicates how effictively the transformer capacity is used in delivering dc power to load for a given ac power.

$$T.U.F = \frac{\text{DC Power delivered to the Load}}{\left(\text{AC Power rating of secondary winding of the transformer}\right)}$$

→ T.U.F is important in power supplies design and helps in finding the power rating of transformer.

- The dc power delivered to the load is

$$\boxed{P_{dc} = I_{dc}^2 R_L} \quad — \; 5.1$$

⇒ I_{dc} → DC value of o/p current
R_L → load resister

$$P_{dc} = I_{dc}^2 R_L \quad — \; ①$$

- Usually the power transformer's are rated for AC power and AC power is specified in terms of Volt-Ampere (VA) rating. (VA rating)
- Thus the capacity of transformer is always specified in terms of RMS value of voltage (V_{rms}) and current (I_{rms})

V_{rms} & I_{rms}

∴ Product of $I_{rms} V_{rms}$ is the VA rating of the secondary winding of the transformer.

∴ AC Power rating of secondarying winding of transformer is $P_{(2^\circ winding)AC} = V_{rms} I_{rms}$ — ②

$$\boxed{P_{(2^\circ winding)}{}_{ac} = V_{rms} I_{rms}} \quad — \; 5.2$$

∴ $$\boxed{TUF = \frac{P_{dc}}{P_{(2^\circ winding)ac}} = \frac{I_{dc}^2 R_L}{V_{rms} I_{rms}}} \quad — \; 5.3 \quad ③$$

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$$\boxed{TUF = \frac{I_{dc}^2 R_L}{V_{rms} I_{rms}}}$$

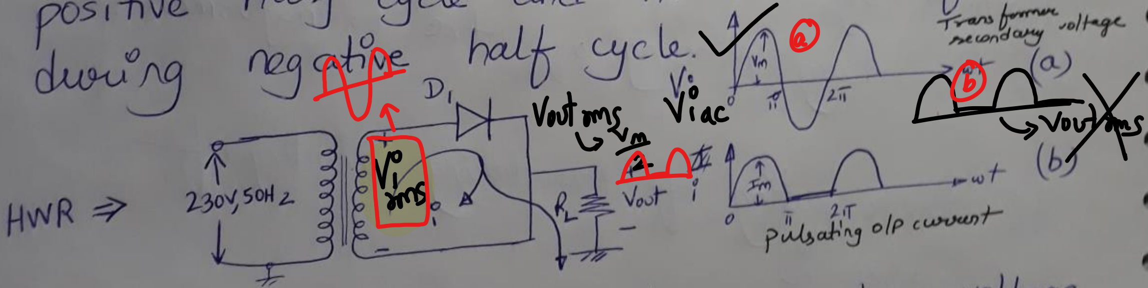
It is the rms value of current that is supplied by secondary winding of the transformer

It is the rms value of the voltage at the secondary winding of the transformer

• For a Half-wave Rectifier:-

→ $T.U.F_{HWR} = ?$

→ In case of H.W.R, current flows through the secondary of transformer, only during positive half cycle and no current flows during negative half cycle.



• In a HWR, transformer will supply a secondary voltage (as shown in fig a) of pure sinusoidal nature

RMS value of such sinusoidal wave is $\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}} = 0.707\, V_m$ — 5.4

• Current supplied by the secondary winding of transformer is a pulsating half sine current (fig b)

RMS value of fig(b) is $\boxed{I_{rms} = \frac{I_m}{2}}$ — 5.5

• Also, dc power supplied to the load ie

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

where, $I_{dc} = \frac{I_m}{\pi}$ ----- for a H.W.R —

↳ DC or average value of o/p current i.

$$P_{dc} = \frac{I_m^2}{\pi^2} R_L \quad — (5.6)$$

$$\therefore \text{T.U.F} = \frac{I_{dc}^2 R_L}{V_{rms} I_{rms}} \quad \text{(From 5.3)}$$

$$TUF = \frac{I_{dc}^2 R_L}{V_{rms} I_{rms}}$$

$$\left(\frac{I_m}{\pi}\right) \quad \left(\frac{V_m}{\sqrt{2}}\right) \quad \left(\frac{I_m}{2}\right)$$

$$\text{ie T.U.F} = \frac{\frac{I_m^2}{\pi^2} \times R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{2}}$$

$$= \frac{2\sqrt{2}\, I_m R_L}{\pi^2 V_m} \quad (\because V_m = I_m R_L)$$

$$= \frac{2\sqrt{2}}{\pi^2} \times \frac{\cancel{V_m}}{\cancel{V_m}}$$

$$\boxed{TUF_{HWR} = 0.287}$$

$$TUF = 0.287 = \frac{P_{dc}}{P_{(2^\circ \text{ winding})\, ac}}$$

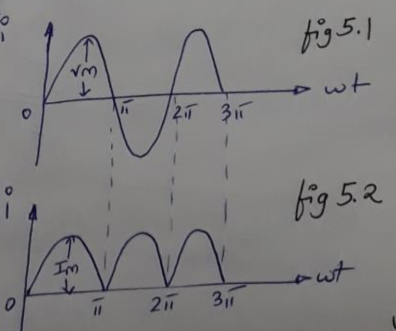
$$\therefore \quad P_{dc} = 0.287 \times P_{(2^\circ \text{ winding})ac}$$

ie $$\boxed{P_{dc} = 28.7\% \text{ of } P_{(2^\circ \text{winding})ac}} \text{ ------ For HWR} \quad (5.7)$$

- This means that only 28.7% of the AC power that will be supplied by the secondary winding of the transformer will be supplied to the Load resistor R_L at the output.

T.U.F for Full-wave Bridge rectifier :-

- In case of full-wave bridge rectifier, we don't use center-tap transformer. Hence, current flows through the secondary both for positive half cycle and for negative half cycle. Thus, both voltage and current through the secondary winding of transformer is sinusoidal in nature.



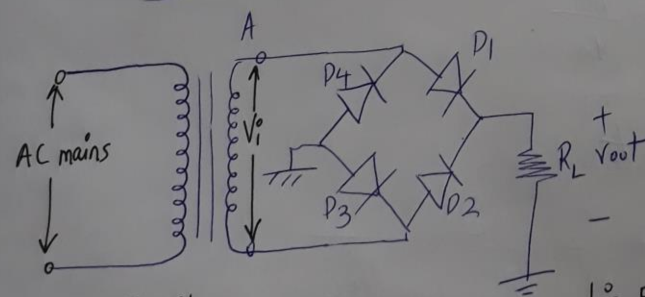


fig Bridge Rectifier

fig 5.1 Transformer secondary voltage 'V_i'

fig 5.2 Rectified o/p current 'i'

- In a FWBR, transformer will supply a secondary voltage V_i (fig 5.1) of pure sinusoidal nature. 51

RMS value of such a sinusoid is $V_{rms} = \frac{V_m}{\sqrt{2}}$

- Current supplied by the secondary winding of transformer is a pulsating sine current (fig 5.2)

RMS value of fig 5.2 is $I_{rms} = \frac{I_m}{\sqrt{2}}$

Also, the dc power supplied to the Load ie

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

where, $I_{dc} = \frac{2 I_m}{\pi}$ --- for a F.W.B.R

↳ DC or average value of O/P current

$\therefore$ $$T.U.F = \frac{I_{dc}^2 R_L}{V_{rms} I_{rm}}$$ (From 5.3)

$V_m = I_m R_L$

$$= \frac{\frac{4 I_m^2}{\pi^2} \times R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}} = \frac{8 I_m^2 R_L}{\pi^2 I_m V_m} = \frac{8}{\pi^2} \frac{I_m R_L}{V_m}$$

$$T.U.F = \frac{8}{\pi^2} \times \frac{V_m}{V_m}$$

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$$\therefore \; T.U.F = \frac{8}{\pi^2}$$

$$\boxed{T.U.F_{FWBR} = 0.81}$$ ----- For a Full-wave Bridge rectifier

ie $$\frac{P_{dc}}{P^{ac}_{(2^\circ winding)}} = 0.81$$

ie $$\boxed{P_{dc} = 0.81 \times P^{ac}_{(2^\circ winding)}}$$

ie $$\underline{P_{dc} \simeq 81\% \text{ of } P^{ac}_{(2^\circ winding)}}$$ ---- For FWBR

This means that only 81% of the AC power that will be supplied by the secondary winding of the transformer will be delivered to the load resistor R_L at the output.

- <u>Observation:-</u>

- Since, maximum portion of AC rated power of secondary winding of the transformer is converted into DC power at the output in case of full-wave bridge rectifier.
- That's why, full-wave bridge rectifier is better than Half-wave rectifier.

I. T.U.F for a Full-Wave Center-tapped Rectifier: 53

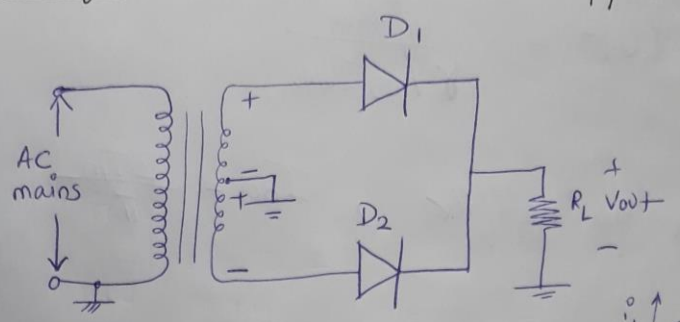

fig: FWCTR

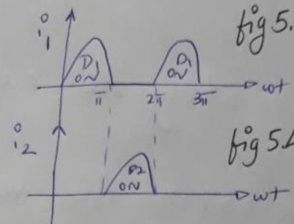

fig 5.3

fig 5.4

- In a full-wave rectifier, the secondary current flows through each half separately in every half cycle. (fig 5.3 & 5.4)

fig 5.3 Current i_1 flowing thr R_L during +ve h.c

fig 5.4 Current i_2 flowing thr R_L during −ve h.c

- While the primary of transformer carries current continuously.
- Hence T.U.F is calculated for primary and secondary windings separately and then the average T.U.F is determined.

ie
$$\boxed{T.U.F_{FWCTR} = \frac{\text{Primary T.U.F} + \text{Secondary T.U.F}}{2}} \quad -(6.1)$$

- Secondary T.U.F $= \dfrac{I_{dc}^2 R_L}{V_{rms} I_{rms}}$

For a center-tap rectifier, $I_{dc} = \dfrac{2I_m}{\pi}$

Secondary AC current $I_{rms} = \dfrac{I_m}{\sqrt{2}}$

Secondary AC voltage $V_{rms} = \dfrac{V_m}{\sqrt{2}}$

ie Secondary T.U.F $= \dfrac{\left(\dfrac{2I_m}{\pi}\right)^2 \times R_L}{\dfrac{V_m}{\sqrt{2}} \times \dfrac{I_m}{\sqrt{2}}}$

$$= \frac{\dfrac{4I_m^2}{\pi^2} \times R_L}{\dfrac{V_m R_L}{2}} \qquad (\because I_m R_L = V_m)$$

$$= \frac{8 I_m^2 R_L}{\pi^2 V_m I_m} = \frac{8}{\pi^2} \frac{I_m R_L}{V_m}$$

$\therefore$ Secondary T.U.F $= \dfrac{8}{\pi^2} = 0.81$ —(6.2)

- In a full-wave center-tapped rectifier, the primary of the transformer is feeding two half-wave rectifiers separately.
- These two half-wave rectifiers work independently of each other but feed a common load.
- We have already derived the T.U.F for half-wave circuit to be equal to 0.287.

Hence, T.U.F for primary winding = 2x T.U.F of half-wave ckt

$$= 2 \times 0.287 = 0.574$$

- Average T.U.F for full wave CT rectifier will be

$$T.U.F_{FWCTR} = \frac{(T.U.F \text{ of primary} + T.U.F \text{ of secondary})}{2}$$

$$= \frac{0.574 + 0.812}{2}$$

$$\boxed{T.U.F_{FWCTR} = 0.693} \quad -(6.3)$$

For a Full-wave center-tap rectifier

ie $T.U.F = \frac{P_{dc}}{P_{ac}} = 0.693$

ie $\boxed{P_{dc} = 0.693 \times P_{ac}}$

ie $P_{dc} = 69.3\%$ of P_{ac} -- For a FWCTR

This means that only 69.3 % of the AC power supplied by the transformer is converted into DC power at the output.

• Note:-

Thus in a full-wave center-tapped rectifier, transformer gets utilized more than the half wave rectifier circuit.

• Comparison between Full-wave center-tap rectifier and bridge Rectifier:-

• Normally, compared to FWCT rectifier, we prefer Full-wave bridge rectifier for following reasons:-

1. The need of center-tap transformer is eliminated.

2. The PIV rating of diode in bridge rectifier is 'V_m', ie half to that of Full-wave Center-tapped rectifier.

3. The main advantage of it is that value of T.U.F for bridge rectifier (TUF = 0.81) is more compared to Full-wave center-tap rectifier (TUF = 0.693).

   Thus in a full-wave bridge rectifier, transformer gets <u>utilized more</u> than the full-wave center-tap rectifier.

4. For the same DC power output, we require more secondary power rating in FWCTR compared to FWBR.

   This means the size and hence the cost of transformer will increase in full-wave center-tapped rectifier.

   Therefore, a smaller transformer may be used than for the FWBR of the same output.

→ Bridge rectifier is thus suitable for high-voltage applications.