Auto Transformer

Acknowledgement: *The materials presented in this lecture has been taken from open source, reference books etc. This can be used only for student welfare and academic purpose.*

Recap

- Transformer efficiency
- Condition for maximum efficiency
- Voltage regulations for lagging, leading and unity power factor load
- Conditions for zero and maximum voltage regulation
- All day efficiency and its needs
- Sumpner’s Test or back to back test
- Polarity test

Lecture-7 Objectives

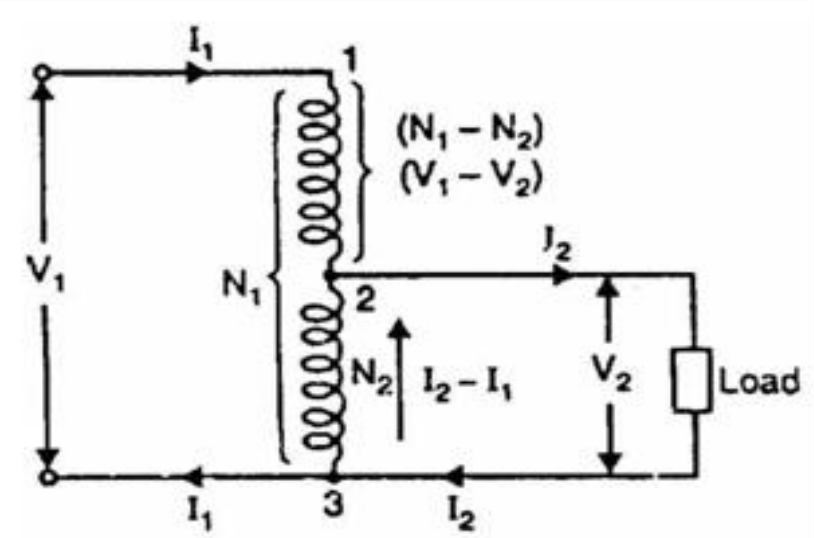
- Needs of auto transformer
- Comparison with two winding ordinary transformer
- Electrical power transfer capability of the auto transformer
- Copper saving of the auto transformer
- Advantages and disadvantages
- Applications

Auto Transformer

- Primary and secondary windings are connected electrically as well as magnetically.
- Therefore, power from the primary is transferred to the secondary conductively as well as inductively (transformer action).
- The voltage transformation ratio K of an ideal autotransformer is,

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1} = K$$

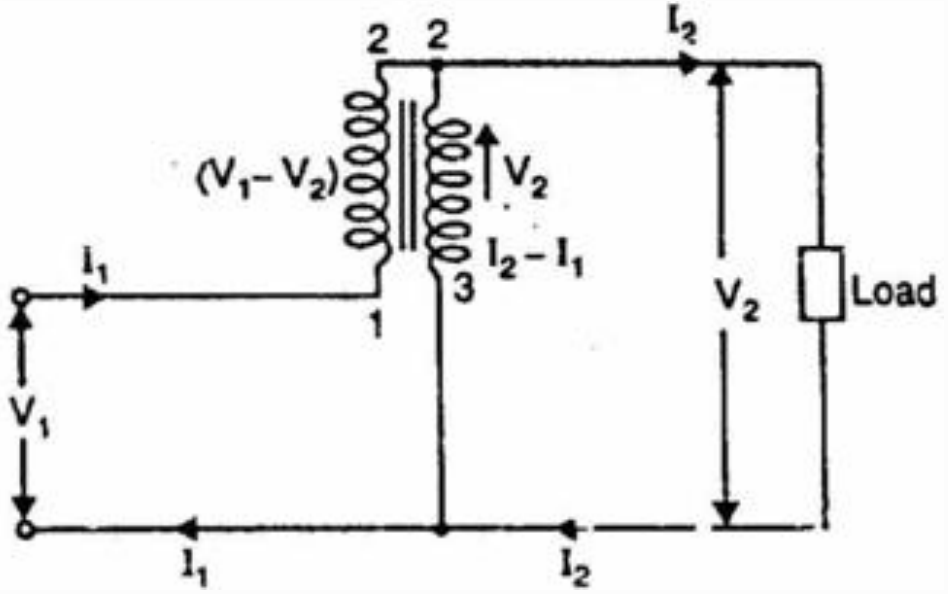
Theory of Autotransformer



- Winding 1-3 - N_1 turns - pri winding
- winding 2-3 - N_2 turns - sec winding
- Input current is I_1
- Output current is I_2
- Portion 1-2 of the wdg has N_1 - N_2 turns and voltage across this portion of the winding is V_1 - V_2.
- The current through the common portion of the winding is I_2 - I_1.

Theory of Autotransformer

- The equivalent circuit of the autotransformer.
- From this equivalent circuit, we have,



$$\frac{V_1 - V_2}{V_2} = \frac{N_1 - N_2}{N_2}$$

$$(N_1 - N_2)V_2 = (V_1 - V_2)N_2$$

$$V_2N_1 - V_2N_2 = V_1N_2 - V_2N_2$$

$$V_2N_1 = V_1N_2$$

$$\frac{N_2}{N_1} = \frac{V_2}{V_1} = K$$

Output of Autotransformer

- Output apparent power = $V_2 I_2$

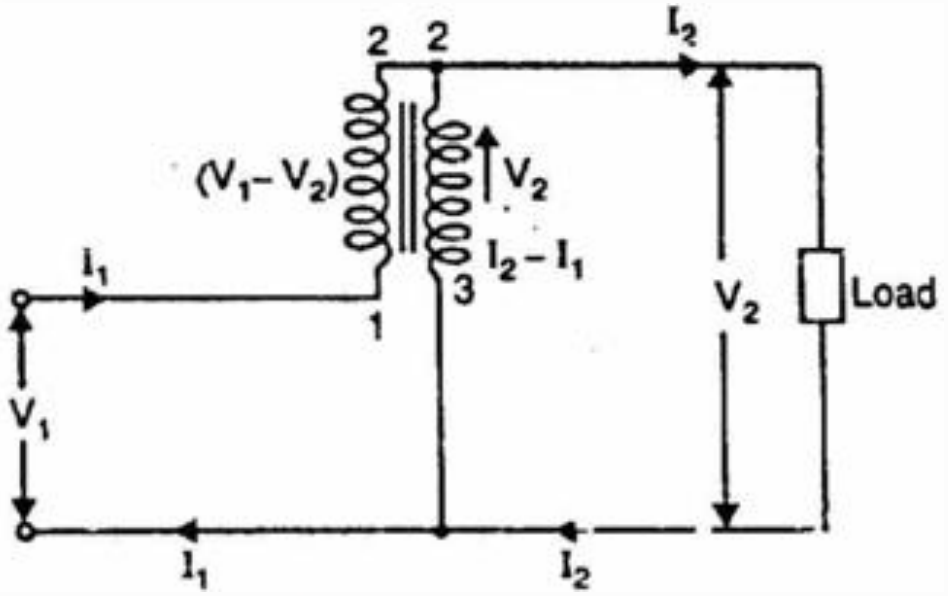
  Apparant power transferred inductively

$$= V_2(I_2 - I_1) = K.V_1\left(\frac{I_1}{K} - I_1\right)$$

$$= K.V_1 I_1\left(\frac{1}{K} - 1\right)$$

$$= K.V_1 I_1\left(\frac{1-K}{K}\right) = V_1 I_1(1-K)$$

$$= Input \times (1-K)$$



Auto Transformer

$$\text{Apparant power transferred conductively} = \text{Input} - \text{Input} \times (1 - K)$$

$$= \text{Input}[1 - (1 - K)] = Input \times K$$

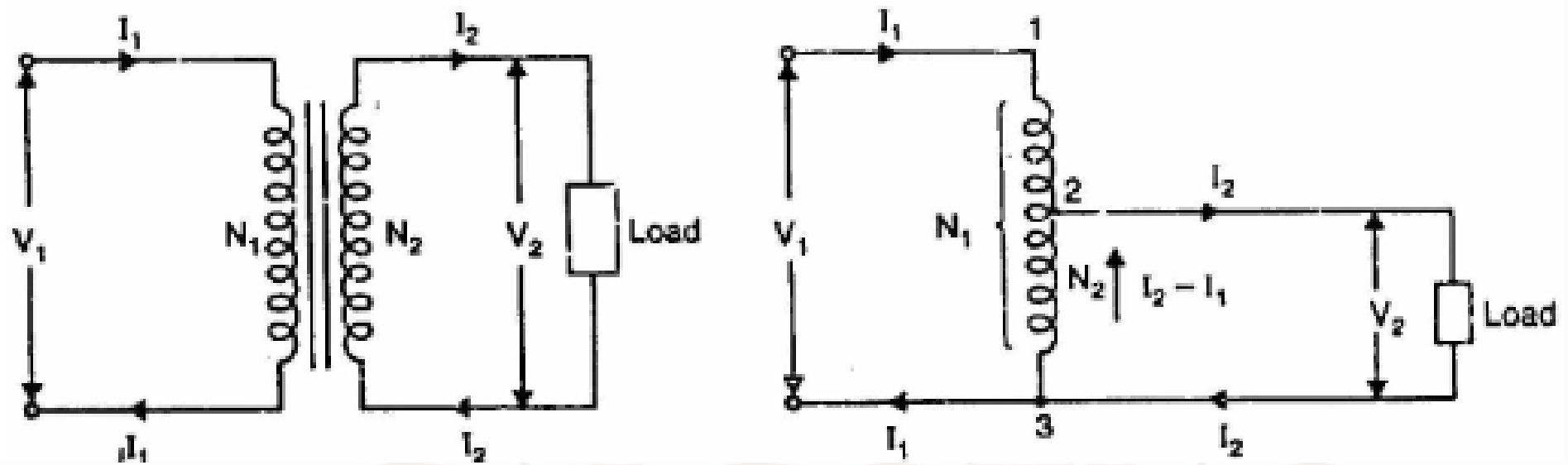
- Suppose the input power to an ideal autotransformer is 1000 W and its voltage transformation ratio K = 0.25. Then,

$$\text{Apparant power transferred inductively} = \text{Input} \times (1 - K) = 1000 \times (1 - 0.25)$$

$$= 750\ W$$

$$\text{Apparant power transferred conductively} = \text{Input} \times K = 1000 \times 0.25 = 250\ \text{W}$$

Saving of Copper in Auto Transformer



- For the same output and voltage transformation ratio, an autotransformer requires less copper than an ordinary 2-winding transformer.
- Weight of Cu required in a winding is α current X turns

Saving of Copper in Auto Transformer

Two winding transformer

- Weight of Cu required α $(I_1N_1 + I_2N_2)$

Autotransformer

- Weight of Cu required in section 1-2 α $I_1 (N_1 – N_2)$
- Weight of Cu required in section 2-3 α $(I_2 – I_1)$ N2
- Total weight of Cu required α $I_1 (N_1 – N_2) + (I_2 – I_1) N_2$

$$\frac{\text{Weight of Cu in autotransformer}}{\text{Weight of Cu in ordinary transformer}} = \frac{I_1(N_1 - N_2) + (I_2 - I_1)N_2}{I_1N_1 + I_2N_2}$$

Saving of Copper in Auto Transformer

$$\frac{\text{Weight of Cu in autotransformer}}{\text{Weight of Cu in ordinary transformer}} = \frac{I_1(N_1 - N_2) + (I_2 - I_1)N_2}{I_1N_1 + I_2N_2}$$

$$= \frac{N_1I_1 - N_2I_1 + N_2I_2 - N_2I_1}{N_1I_1 + N_2I_2} = \frac{N_1I_1 + N_2I_2 - 2N_2I_1}{N_1I_1 + N_2I_2}$$

$$= 1 - \frac{2N_2I_1}{N_1I_1 + N_2I_2} = 1 - \frac{2N_2I_1}{2N_1I_1} \qquad (\because\ N_2I_2 = N_1I_1)$$

$$= 1 - \frac{N_2}{N_1} = 1 - K$$

$$Weight\ of\ Cu.in\ auto\ tfr\ (W_a) = \left(1 - K\right) \times weight\ of\ Cu.in\ ordinary\ tfr\ (W_o)$$

Saving of Copper in Auto Transformer

$$W_a = (1 - K) \times W_o$$

$$\therefore \text{ Saving in Cu} = W_o - W_a = W_o - (1 - K)W_o = K\, W_o$$

$$\text{Saving in Cu} = K \times \text{Wt. of Cu in ordinary transformer}$$

- Thus if K = 0.1, the saving of Cu is only 10% but if K = 0.9, saving of Cu is 90%.
- Therefore, saving of Cu is more when K is nearer to 1.

Advantages of Autotransformers

- An autotransformer requires less Cu than a two -winding transformer of similar rating.
- Autotransformer operates at a higher efficiency than a two-winding transformer of similar rating.
- An autotransformer has better voltage regulation than a two-winding transformer of the same rating.
- An autotransformer has smaller size than a two-winding transformer of the same rating.

Advantages of Autotransformers

- An autotransformer requires smaller exciting current than a two-winding transformer of the same rating.
- These advantages decrease as the ratio of transformation increases. So an autotransformer has advantages only for low values of transformation ratio.

Disadvantages of Autotransformers

- There is a direct connection between the primary and secondary. Therefore, the output is no longer isolated from the input.
- It is not safe for stepping down a high voltage to a low voltage.
- The short - circuit current is much larger than for the two-winding transformer of the same rating.
- This reduces the effective resistance and reactance.

Applications of Autotransformers

- Autotransformers are used to compensate for voltage drops in transmission and distribution lines. When used for this purpose, they are known as booster transformers.
- Autotransformers are used for reducing the voltage supplied to a.c. motors during the starting period.
- Autotransformers are used for continuous variable supply.

Auto Transformer

Summary

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- Electrical power transfer capability of the auto transformer
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