I Devices

Part 1 Transformer

1.1 what is a transformer

- The transformer is a device that changes AC energy at one voltage level to another voltage level through the action of he magnetic fields.

1.2 What does a transformer do?

- Changing the voltage level
- Marching source and load impedances of maximum power transfer.
- Electrical isolation.
- Does not change the power and the frequency of the signal.

1.3 How the transformer works?

1.3.1 The main principles

- Electromagnetism:
  the current make the magnetism.
- Electromagnetic Induction:
  the magnetism produce the electrical current.

1.3.2 Principle of operation

- A changing magnetic field induces an emf.(By Faraday)
- $E = -\frac{d\Phi B}{dt}$
- The AC input current produce the magnetic flux. Then the magnetic flux induces another AC voltage in the secondary winding.

1.4 Voltage and current ratios

1.4.1 Voltage ratio

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

1.4.2 Utilisation of magnetic core material and saturation

- $\Phi = \dfrac{NI}{S}$, and S is the reluctance.
- $V_1 = N_1 \dfrac{d\Phi}{dt} = N_1 \omega \Phi_{max} \cos \omega t$
- $\Phi_{max} = B_{max} A$
- $V_{1,rms} = N_1 B_{max} A \omega / \sqrt{2}$

1.4.3 Current ratio

- $\Phi S = N_1 I_1 - N_2 I_2$
- S is usually small
- $N_1 I_1 \approx N_2 I_2$
- $\dfrac{I_2}{I_1} = \dfrac{N_1}{N_2}$

1.4.4 Equivalent circuits of an ideal transformer

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

$$I_2 = \frac{N_1}{N_2} I_1$$

$$V_2 I_2 = V_1 I_1$$

1.4.5 Choice of the turns

- Choose turns to ensure core does not saturate.
- Higher voltage requires more turns.
- Higher f requires more turns.
- Higher current requires thicker coil.

1.5 The equivalent circuit

1.5.1 Practical transformer

- Real transformer
  - have losses
  - have leakage flux
  - have finite permeability of magnetic core.
- Real power losses
  - resistance in winding (I^2R)
  - core losses due to eddy current and hysteresis.

1.5.2 Equivalent circuit of practical transformer

- The inductance and resistance can be expressed as a series of resistance and inductors.
- The magnetizing inductance can be expressed as a parallel of resistance and inductor.
- If we treat $a = \frac{N_1}{N_2}$, the load at the secondary side is Z_L
- The equivalent of $R, Z, X(Inductance)$:
  - $R_2' = a^2 R_2$
  - $X_2' = a^2 X_2$
  - $Z_L' = a^2 Z_L$
  - $I_2' = \frac{I_2}{a}$
- This is called secondary current referred to primary.
- The circuit can be simplified by using R_{e1} and X_{e1} to simplify the total R and X.
- Z_{e1} is to express the sum of R and jX_{e1}
- The referring to the secondary circuit is similar, which we should use the inverse of the a to replace a.
  - $V_1' = \frac{V_1}{a}$

1.6 The determination of transformer parameters

1.6.1 Open circuit test (O.C.)

- Performed on L.V. side and keeping H.V. open circuited.
- The test is to determine the magnetic impedance value ,R_0, X_0
- Gradually increase the voltage till reach the rated voltage.