PHASOR DIAGRAM OF TRANSFORMER

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IMPORTANT POINTS FOR PHASOR OF TRANSFORMER

- Transformer when excited at no load, only takes excitation current which leads the working Flux by Hysteretic angle $\alpha$.
- Excitation current is made up of two components, one in phase with the applied Voltage $V$ is called Core Loss component ($I_c$) and another in phase with the working Flux $\Phi$ called Magnetizing Current ($I_m$).
- Electromotive Force (EMF) created by working Flux $\Phi$ lags behind it by 90 degree.
- When Transformer is connected with a Load, it takes extra current $I'$ from the Source so that $N_1I' = N_2I_2$ where $I'$ is called load component of Primary Current $I_1$. 
IMPORTANT POINTS FOR PHASOR OF TRANSFORMER

- So under load condition, \( I_1 = \) Primary Current, is phasor Sum of \( I' \) and Excitation Current \( I_e \).
NO LOAD PHASOR OF A TRANSFORMER

Secondary Open
NO LOAD PHASOR OF A TRANSFORMER

- Working Flux $\Phi$ taken as Reference
NO LOAD PHASOR OF A TRANSFORMER

- Excitation Current $I_e$ leading $\Phi$ by $\alpha$. 
NO LOAD PHASOR OF A TRANSFORMER

- Induced EMF $E_1$ and $E_2$ lagging Flux by 90 degree.

$E_1, E_2 = V_2$
NO LOAD PHASOR OF A TRANSFORMER

- $V_1' = -E_1$

$E_1, E_2 = V_2$
NO LOAD PHASOR OF A TRANSFORMER

- Voltage drop \( r_1I_e \) in Primary.

\[ V_1' = -E_1 \]

\[ r_1I_e \]

\[ I_c \]

\[ I_e \]

\[ \alpha \]

\[ I_m \]

\[ E_1, E_2 = V_2 \]
NO LOAD PHASOR OF A TRANSFORMER

Voltage drop IeX1 in Primary due to reactance.

\[ V_1' = -E_1 \]

\[ \alpha \]

\[ I_c, I_m, I_e \]

\[ E_1, E_2 = V_2 \]
NO LOAD PHASOR OF A TRANSFORMER

Source Voltage $V_1 = V_1' + r_1 I_e + j I_e X_1$, phasor sum.

$V_1' = -E_1$

$E_1, E_2 = V_2$
No load Power Factor = $\cos \Theta$

- $V_1'$ = $-E_1$
- $E_1, E_2 = V_2$
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- As load is inductive, secondary current will lag secondary load voltage $V_2$ by some angle.
- $r_1 =$ Primary winding Resistance
- $X_1 =$ Primary winding leakage Reactance
- $r_2 =$ Secondary winding Resistance
- $X_2 =$ Secondary winding leakage Reactance
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- Working Flux $\Phi$ is taken as reference.
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

\[ I_e \]

\[ \alpha \]

\[ \emptyset \]
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

\[ \text{E1, E2} \]

\[ \text{I}_e \]

\[ \alpha \]

\[ \emptyset \]
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

\[ V_1' = -E_1 \]

\[ \alpha \]

\[ I_e \]

\[ E_1, E_2 \]

\[ \emptyset \]
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- Working Flux $\phi$ is taken as reference.
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- Working Flux $\Phi$ is taken as reference.
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- Working Flux $\Phi$ is taken as reference.
Working Flux $\varnothing$ is taken as reference.
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

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PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- $E_2 = V_2 + I_2r_2 + jI_2X_2$, phasor sum
PHASOR OF A TRANSFORMER FOR INDUCTIVE LOAD

- Primary Power Factor = \( \cos \theta_1 \), angle between \( V_1 \) & \( I_1 \).
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

- As load is capacitive, secondary current will lead secondary load voltage $V_2$ by some angle.
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

- Working Flux $\Phi$ is taken as reference.
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

E1, E2

α

Ie

∅
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = -E_1 \]
\[ \alpha \]
\[ I_e \]
\[ V_2 \]
\[ E_1, E_2 \]
\[ \varnothing \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = -E_1 \\]

\[ \theta \]

\[ I_e \]

\[ I_2 \]

\[ \theta_2 \]

\[ E_1, E_2 \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = -E_1 \]

\[ I_1' \]

\[ \phi \]

\[ I_e \]

\[ \theta_2 \]

\[ E_1, E_2 \]

\[ \theta \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = -\frac{E_1}{E_1} \]

\[ I_1' \]

\[ I_1 \]

\[ I_1, I_2, I_e \]

\[ \alpha \]

\[ \Theta_1, \Theta_2 \]

\[ E_1, E_2 \]

\[ \emptyset \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = -E_1 \]
\[ I_1' \]
\[ I_1r_1 \]
\[ jI_1X \]
\[ \alpha I_e \]
\[ E_1, E_2 \]

\[ \theta_2 \]
\[ I_2 \]
\[ I_1 \]
\[ I_e \]
\[ \alpha \]
\[ \theta \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1 = V_1' + I_1 r_1 + j I_1 X_1, \text{ phasor sum} \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = \ldots \]

- \[ E_1 \]
- \[ I_1 \]
- \[ r_1 \]
- \[ jX_1 \]
- \[ V_1 = V_1' + I_1r_1 + jI_1X_1, \text{ phasor sum} \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

\[ V_1' = -E_1 \]

\[ I_1' \]

\[ I_1 \]

\[ I_{1r1} \]

\[ jI_1X \]

\[ E_2 = V_2 + I_2r2 + jI_2X2, \text{ phasor sum} \]
PHASOR OF A TRANSFORMER FOR CAPACITIVE LOAD

$V_{1}' = -E_1$

$I_1'$

$I_1$

$I_{1r1}$

$jI_1X$

$V_{1}' = -E_1$

$I_1$

$E_2 = V_2 + I_2r_2 + jI_2X_2$, phasor sum

$E_1, E_2$

$V_2$

$I_2$

$I_{2r2}$

$jI_2X_2$

$\Theta_2$

$\Theta_1$

$I_e$

$\alpha$

$\phi$

$\alpha$

$\phi$

$\phi$
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

- For Resistive Load, load current will be in phase with the load Voltage V2.
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

- Working Flux $\Phi$ is taken as reference.
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

E₁, E₂

Iₑ

α

∅
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]

\[ \alpha \]

\[ I_e \]

\[ E_1, E_2 \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]

\[ I_e \]

\[ \alpha \]

\[ V_2 \]

\[ E_1, E_2 \]

\[ \emptyset \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]

\[ \angle I_e \]

\[ E_1, E_2 \]

\[ I_2 \]

\[ V_2 \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]

\[ I_1' \]

\[ I_e \]

\[ V_2 \]

\[ I_2 \]

\[ E_1, E_2 \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]

\[ I_1' \]

\[ I_1 \]

\[ I_e \]

\[ V_2 \]

\[ I_2 \]

\[ E_1, E_2 \]

\[ \alpha \]

\[ \emptyset \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]

\[ I_1' \]

\[ I_1 \]

\[ I_e \]

\[ I_2 \]

\[ V_2 \]

\[ E_1, E_2 \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]
\[ I_1' \]
\[ I_1 \]
\[ I_{r1} \]
\[ jI_1X_1 \]
\[ I_e \]
\[ \alpha \]

\[ V_2 \]
\[ I_2 \]
\[ E_1, E_2 \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1 = V_1' + I_1r_1 + jI_1X_1, \text{ phasor sum} \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]
\[ I_1' \]
\[ I_1 \]
\[ jI_1X_1 \]
\[ V_1 \]
\[ \varnothing \]
\[ I_e \]
\[ \alpha \]
\[ I_2 \]
\[ V_2 \]
\[ I_2r_2 \]
\[ E_1, E_2 \]
PHASOR OF A TRANSFORMER FOR RESISTIVE LOAD

\[ V_1' = -E_1 \]
\[ I_1' \]
\[ I_{1r1} \]
\[ jI_1X_1 \]
\[ V_2 \]
\[ E_2 = V_2 + I_{2r2} + jI_2X_2, \text{ phasor sum} \]

\[ \alpha \]

\[ I_2 \]
\[ I_{2r2} \]
\[ jI_2X_2 \]

\[ E_1, E_2 \]

\[ \emptyset \]
COMMENTS? / QUESTIONS???

Thank you ...