APPENDIX B

Armature Reaction

Flux produced by armature winding (when current I_a flows) reacts with the flux set up by the rotor field, causing a redistribution of the total resultant flux. Such an interaction between the two fluxes is called armature reaction $\rightarrow$ This affects the terminal voltage V.

Let us examine a sequence of events that will take place when the generator delivers a load at unity pf.

(a) If ϕ_F = rotor flux
Then E must lag ϕ_F by 90° (stated before)

(b) I_a is in phase with V (UPF load)

(c) I_a produces a flux ϕ_{ar} which is in phase with I_a.
Effective flux $\phi_T = \phi_F + \phi_{ar}$.

(d) Flux ϕ_{ar} produces an EMF E_{ar} in the armature winding.
E_{ar} = armature reaction EMF, and it lags ϕ_{ar} by 90°.

⇒ Effective generated voltage

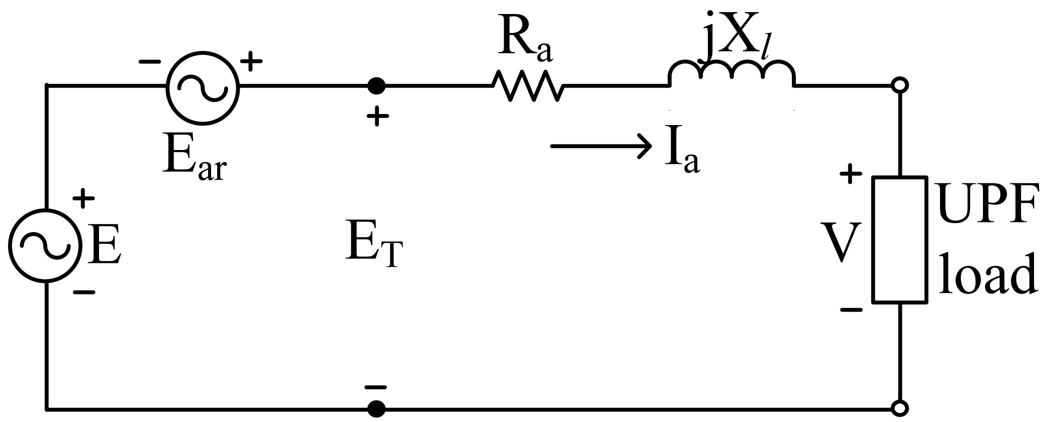
$E_T = E + E_{ar} \Rightarrow E = E_T - E_{ar}$

(e) Terminal voltage V is obtained by subtracting I_aR_a & jI_aX_l drops from E_T.

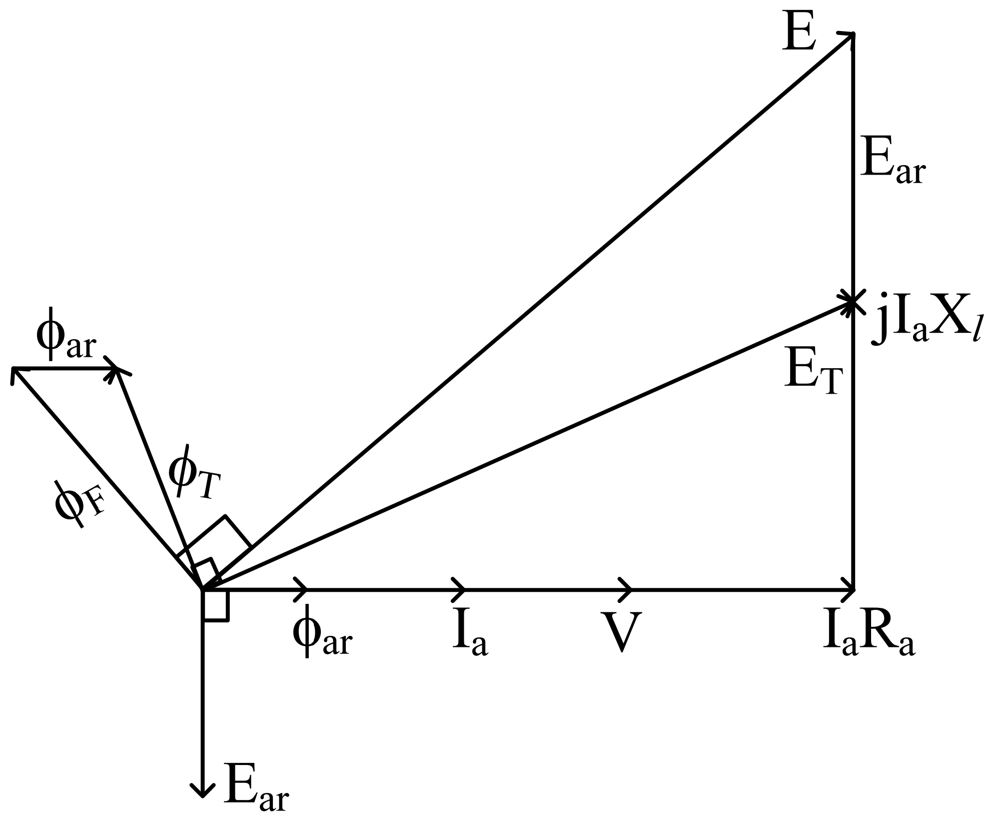
⇒ $E_T = I_aR_a + jI_aX_l + V$

Note from the phasor diagram that

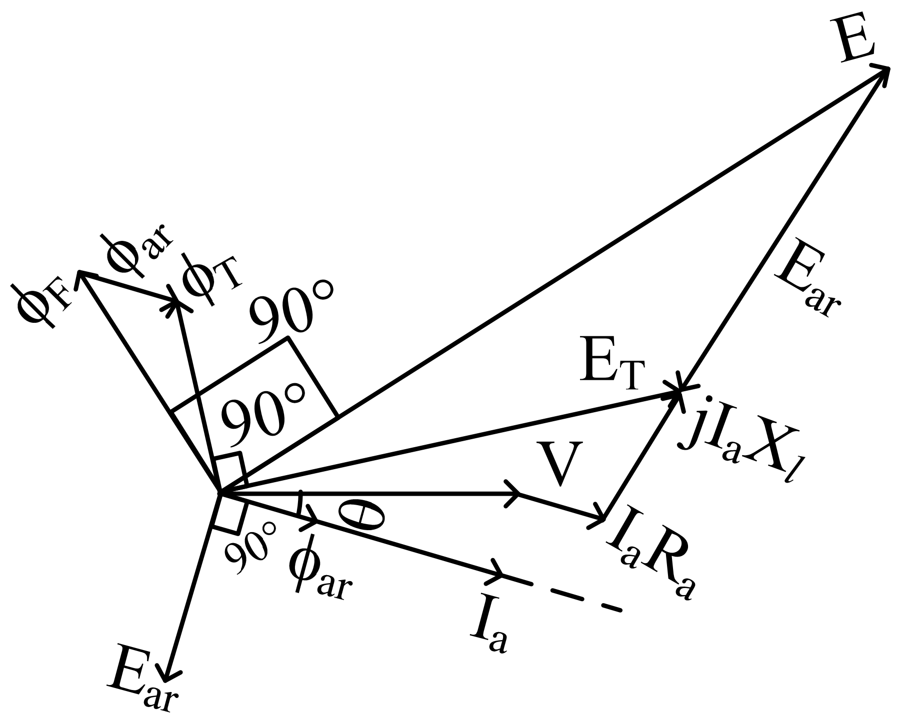
- the armature reaction has reduced the effective flux per pole (from ϕ_F to ϕ_T) at UPF load.
- armature reaction has reduced the terminal voltage.



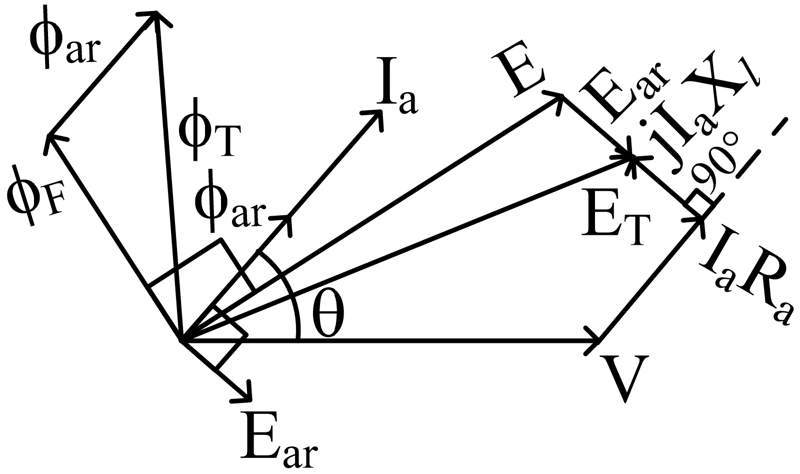
Equiv. CKT. showing the induced EMF in the armature winding <u>due to the armature reaction</u>.



Phasor diagram showing effect of armature reaction when load is UPF load. ($\phi_T < \phi_F$, V < E)



Lagging PF load ($\phi_T < \phi_F$, V < E)



Leading PF loads ($\phi_T > \phi_F$, V > E)

Since E_{ar} lags I_a (& ϕ_{ar}) by 90°, we can also express it as

$E_{ar} = -jI_aX_{ar}$ where X_{ar} = armature reaction reactance

Since both X_{ar} & X_l are present all the time & it is rather difficult to separate them, we combine them together, and

$X_s = X_{ar} + X_l$ where X_s is called <u>synchronous reactance</u>.

$X_s >> R_a$ (usually)

Z_s = synchronous impedance per phase

= $R_a + jX_s$

$\therefore \; E = I_aR_a + jX_sI_a + V$

$\Rightarrow V = E - I_aZ_s$

Neglecting R_a, $Z_s \simeq jX_s = j(X_{ar} + X_l)$