Synchronous Generator Operating Alone w/ Loads

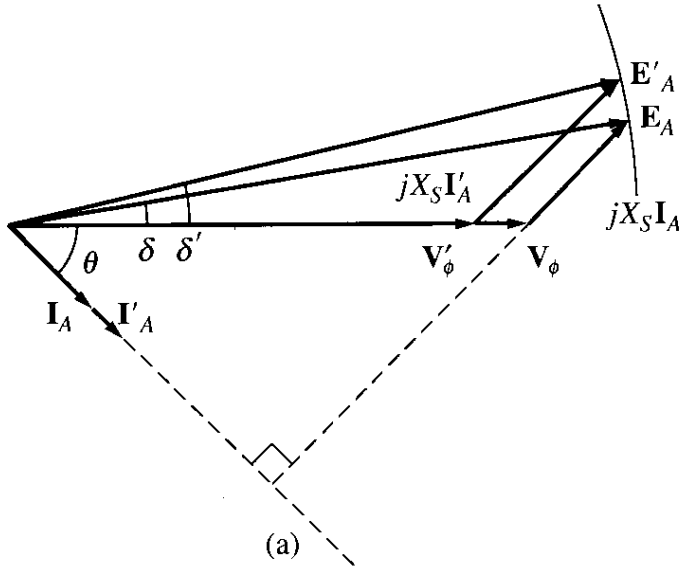
Consider a synchronous generator operating alone supplied by a constant magnetic flux ϕ and turning a constant speed ω_m.

$\Rightarrow \left|\overline{E}_A\right| = E_A$ is constant.

Lagging PF Load

- First, the generator supplies a load with some lagging PF (angle θ) with a load current $\overline{I}_A = I_A \angle -\theta$. The phasor diagram is shown below with unprimed phasor voltages.
- Next, the generator supplies a heavier/larger load with the same lagging PF (angle θ) with a load current $\overline{I}_A' = I_A' \angle -\theta$ where $I_A' > I_A$. The phasor diagram is shown below with primed phasor voltages. Note $jX_S\overline{I}_A'$ is longer than $jX_S\overline{I}_A$.
- Since $\left|\overline{E}_A\right| = \left|\overline{E}_A'\right| = E_A$ is constant, this forces $\left|\overline{V}_\phi'\right| < \left|\overline{V}_\phi\right|$.
- **The output phase voltage (and terminal voltage V_T) decreases (sags) with heavier lagging PF loads. $\Rightarrow$ Result matches our experience/expectation.**

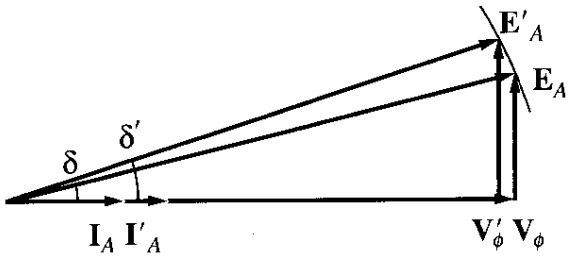
Figure 5–23 | The effect of an increase in generator loads at constant power factor on its terminal voltage: (a) Lagging power factor.



Unity PF Load

- First, the generator supplies a load with a unity PF (angle 0) with a load current $\overline{I}_A = I_A \angle 0$. The phasor diagram is shown below with unprimed phasor voltages.
- Next, the generator supplies a heavier/larger load, still with a unity PF, with a load current $\overline{I}_A' = I_A' \angle 0$ where $I_A' > I_A$. The phasor diagram is shown below with primed phasor voltages. Note $jX_S\overline{I}_A'$ is longer than $jX_S\overline{I}_A$.
- Since $|\overline{E}_A| = |\overline{E}_A'| = E_A$ is constant, this forces $|\overline{V}_\phi'| < |\overline{V}_\phi|$ but the effect is not as dramatic (another argument for PF ~ 1).
- **The output phase voltage (and terminal voltage V_T) decreases (sags) slightly with heavier unity PF loads. ⇒ Result matches our experience/expectation.**

Figure 5–23 The effect of an increase in generator loads at constant power factor on its terminal voltage: (b) Unity power factor.

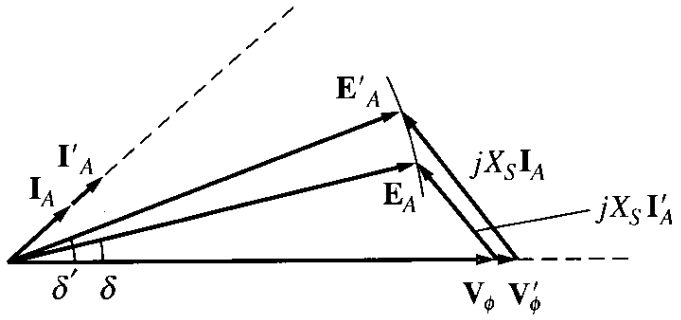


(b)

Leading PF Load

- First, the generator supplies a load with some leading PF (angle θ) with a load current $\overline{I}_A = I_A \angle \theta$. The phasor diagram is shown below with unprimed phasor voltages.
- Next, the generator supplies a heavier/larger load with the same leading PF (angle θ) with a load current $\overline{I}_A' = I_A' \angle \theta$ where $I_A' > I_A$. The phasor diagram is shown below with primed phasor voltages. Note $jX_S\overline{I}_A'$ is longer than $jX_S\overline{I}_A$.
- Since $\left|\overline{E}_A\right| = \left|\overline{E}_A'\right| = E_A$ is constant, this forces $\left|\overline{V}_\phi'\right| > \left|\overline{V}_\phi\right|$.
- **The output phase voltage (and terminal voltage V_T) <u>increases</u> with heavier leading PF loads. $\Rightarrow$ Counterintuitive result.**

Figure 5–23 | The effect of an increase in generator loads at constant power factor on its terminal voltage: (c) Leading power factor.



(c)