**EE2029 Solution for week 5 assignment**

1. A 500 kVA, 11kV three-phase wye-connected synchronous generator has a synchronous reactance of 6 Ω and a negligible armature resistance. At a certain field current, the generator delivers rated load at 0.8 leading power factor at 11kV. For the same excitation, what is the armature current and power factor when the input torque is reduced such that the real power output is one third of the previous case?

**Solution:**

Per-phase terminal voltage $V = \frac{11000}{\sqrt{3}} = 6350.85\angle 0^o\ V.$

Line current for load : $I_L = \frac{|S_{3\phi}|}{\sqrt{3}\times V_{LL}}\angle + \cos^{-1}(power\ factor)$

$$= \frac{500{,}000}{\sqrt{3}\times 11{,}000}\angle + \cos^{-1}(0.8) = 26.24\angle 36.87^o$$

Generator excitation voltage $E = V + I \times (R_a + jX_a) = 6350.85\angle 0^o + 26.24\angle 36.87^o \times j6 =$

$= 6257.65\angle 1.15^o$ V

When excitation is kept constant, magnitude of $E$ will remain same.

When real power is changed, the power angle $\delta$ will change.

$\frac{P_{new}}{P_{old}} = \frac{\sin\delta_{new}}{\sin\delta_{old}} \to \delta_{new} = \sin^{-1}(\sin\delta_{old} \times \frac{P_{new}}{P_{old}}) = \sin^{-1}(\sin 1.15^o \times \frac{1}{3}) = 0.383^o$

$E_{new} = 6257.65\angle 0.383^o\ V$

$I_{new} = \frac{E_{new} - V}{R_a + jX_a} = \frac{6257.65\angle 0.383^o - 6350.85\angle 0^o}{j6} = 17.05\angle 65.86^o A$

New power factor $\cos(65.86^o) = 0.409\ leading.$

2. Two three-phase generators (G1 and G2) supply power together to a three-phase load connected to the common bus. Generator G1 is a 75kVA, 6.6kV, 50 Hz three-phase wye-connected synchronous generator. It has a resistance of 0.2 Ω, a synchronous reactance of 6Ω per phase and supplies 50kW at 0.8 lagging power factor. Generator G2 is a 100kVA, 6.6kV, 50 Hz three-phase wye-connected synchronous generator. G2 has negligible resistance and a synchronous reactance of 8 Ω per phase. The three-phase load draws a total of 80kW at 6.6kV with a leading power factor of 0.9.
   a) Determine the real power and the reactive power supplied by the generator G2.
   b) Determine the per-phase excitation voltage of generator G2.

**Solution:**

The load voltage is 6.6kV line-to-line.

Per-phase load voltage $V_L = \frac{6600}{\sqrt{3}} = 3810.51\angle 0^o\ V$ is the common bus voltage (terminal voltage) for both generators.

Load current $I_L = \frac{80{,}000}{\sqrt{3}\times 6600\times 0.9}\angle \cos^{-1}(0.9) = 7.776\angle 25.84^o\ A$

Current of generator 1, $I_{G1} = \frac{50{,}000}{\sqrt{3}\times 6600\times 0.8}\angle -\cos^{-1}(0.8) = 5.467\angle -36.87^o\ A$

Current of generator 2, $I_{G2} = I_{load} - I_{G1}$

$$= 7.776\angle 25.84^o - 5.467\angle -36.87^o = 7.167\angle 68.52^o A$$

a) Complex power of generator 2 $S_{G2} = 3VI_{g2}^* = 3 \times 3810.51\angle 0^o \times 7.167\angle -68.52^o =$

$$= 30000 - j76239$$

Real power supplied by generator 2 = 30,000 W

Reactive power supplied by generator 2 = 76,239 VAr

b) $E_2 = V + I_{G2} \times (jX_{a2}) = 3810.51\angle 0^o\ V + 7.167\angle 68.52^o \times j8 = 3757.21\angle 0.32^o\ V$