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If the generator is, for example, stated as 50 MVA, 12 kV and X = 0.08, does the 12 kV tell you the terminal voltage of the generator.
The 12 kV value tells you the rated line-to-line terminal voltage of the generator. It does not, however, imply that the operating voltage is 12 kV unless the question says that it operates at rated voltage

In the calculation of the per unit system, we are always asked to calculate the terminal voltage of the generator after obtaining the V pu and I pu of the load. And it's always the case that we will get the terminal voltage value above 12 kV such as 15 kV at the terminal of generator.
Yes, it is possible that generator terminal voltage may exceed the rated value. However, you should know that the terminal voltage may also fall below 12 kV.

Why is it the case?
If the generator is operating alone and overexcited, you may get a terminal voltage higher than 12 kV. Other operating scenarios with a generator terminal voltage exceeding 12 kV are possible too.

T3, Q3 (b) (ii) : In order to find the reactive power, I need to work out the current passing thru the passing thru the jX(tr). So I apply the equation:

E(2) = I(2)*(jX(tr) + jX(s)) + V
I(2) = (E(2) - V)/(jX(tr) + jX(s))
=> I(2) = (1.0776<48.4deg - 1<0deg)/1.51<90deg
and my I(2) works out to be 0.566<-160deg but the actual value is 0.566<19.49deg
I(2) = (1.0776<48.4deg - 1<0deg)/1.51<90deg
= [(0.71544 + j0.8058) – 1]/1.51<90deg
= [-0.284553 + j0.8058]/1.51<90deg
= 0.8548<109.45deg/1.51<90deg
= 0.566<19.45deg

P61 under Synchronous Machine: What is the main difference between "theta"(power factor angle- pg 4) and power or torque angle of the machine?
The power factor (pf) angle, theta, is the phase angle between the load voltage and load current. It can have a value from 0 to 1 and cannot become a negative value. A zero pf value means the load is purely reactive (can be purely inductive, lagging pf or purely capacitive, leading pf). A unity pf value means that the load is purely resistive. A lagging pf load (1> pf > 0) means that the load current is lagging the load voltage. This means that the load has a combination of R and X. Likewise, a leading pf load (1> pf > 0) means that the load has a combination of R and C.

The power angle (delta) is the phase angle between the terminal voltage and internal induced emf. It is also the torque angle (also represented as delta) between the rotor and stator magnetic fields used in the torque generation and calculation. In our treatment of synchronous generators, we are not so much concerned with the torque generation as we are more interested in the electric power generation. The torque equation has never been brought out for discussion. This is usually discussed when the synchronous machine operates as a motor.

P60 under synchronous machine: From the equivalent circuit, can I say that Xs is always positive (jXs) regardless lagging load or leading load?
Yes, it is always positive.

In the lecture ntoes, the flux= Mf*If*sin(wt), what's the Mf mentioned?
Mf is the mutual inductance between the rotor field winding and the stator field winding.

In the synchronous generator part, it is mentioned that the real power is controlled by the mechanical power input. However the reactive power is determined by If. How would you explain it?
Yes, Pmech = Pelec (assume lossless conversion) since electrical power is obtained by converting the mechanical power (torque) driving the steam turbine. This mechanical power needs to overcome the increase in counter electromagnetic torque in the synchronous generator due to load increase (electrical power output). Hence, if you want to reduce the mechanical power input, you must reduce the electrical power output first. Otherwise, the speed of the synchronous generator or frequency will drop. In actual operation, if the electrical load continues to increase, then the governor will ensure that the steam valve is opened wider to stabilize the speed (frequency) after a small time delay.

The field current (If) controls the magnitude of the internal generated voltage E. If you increase If, E will increase such that E is greater than V, then the reactive power is likely to flow from the synchronous generator to the load. Conversely, if you decrease If, E will decrease such that E is less than V, then the reactive power is likely to flow from the load to the synchronous generator.

What are the factors that affect the power angle in synchronous generator (excitation control)?
The factors that affect the power angle are:
a) Change in real power consumption by the load: An increase in Pload increases the power angle in the synchronous generator. Conversely, a decrease in Pload reduces the power angle. We assume that the field excitation and terminal voltage did not change.
b) If you assume that the Pload and terminal voltage are constant, then an increase in filed current (If) will result in an increase in the internal generated EMF. This will then result in a decrease in power angle since E1*sin delta1 = E2*sin delta2. Conversely, a decrease in field current will result in a decrease in E and hence an increase in power angle.

What are the factors that affect the power factor in synchronous generator (excitation control)?

The factors that affect the power angle are:

a) Change in the real and/or reactive power consumption by the load: An increase in Pload will result in an improvement in the power factor angle, i.e. smaller pf angle. We assume that Qload did not change. Likewise, an increase in Qload will result in a poorer pf angle, i.e. bigger pf angle. In the latter case, we assume that Pload did not change.
b) If you assume that the Pload and terminal voltage are constant, then an increase in filed current (If) will result in an increase in internal generated EMF. This will then result in a decrease in pf angle (better pf) if you had a leading load before. Otherwise, this will result in an increase in the pf angle (poorer pf) if you had a lagging load before.

For the lecture notes P82, review exercise10.2, I'm converting P and Q to p.u. value then set up the 2 simultaneous equations (P=VEsin(power angle)/X and Q=VEcos(power angle)-V^2/X) to solve for X and power angle. Is this method correct? Because the answer I got is a bit different from the given ans. (My answers: E=1.04pu, V=1pu, P=0.97pu, Q=0.2425pu)

This could be one of the possible solution techniques. You said that your answer is a bit off. I assume that it is small like what we usually observe in round-off errors. If this is the case, then I think it should be fine. Going through the equations and numbers that you sent me, I notice that you forgot to divide the first term VEcos(power angle) of Q=VEcos(power angle)-V^2/X) by X. Your E has a bit of round-off errors. You should keep more significant digits such as E = 1.04348. Also, in solving the above equation, you should use the following relationship, cos^2(power angle) + sin^2(power angle) = 1 to get rid of the power angle. You would then solve the quadratic equation involving X only.

Exercise 11 Part c: To find the power angle, do we use Ia[cos(theta)] proportionate to sin(power angle)? If so, how to we find the Ia (armature current) in part c of the question? If not, how do we solve this question?

You need to draw out the phasor diagram of this problem. You will see that the angle opposite E (or the angle between the V and IX phasors is 90+ 31.78 degrees). The phaosr diagram has a triangle that starts from the V phasor (at 0 degree reference). It then goes through the jIX phasor (voltage drop across the synchronous reactance) and finally closes the triangle with the E phasor.

The Cosine formula is c**2 = a**2 + b**2 – 2 * a * b cos theta

c = E, a = V and b = I*X and theta = 90 + 31.78 degrees. The angle is more than 90 degrees because we have lagging current (pf = 0.85). Using the cosine formula, we have,

E**2 = V**2 + (IX)**2 + V*(IX) Cos (90 + 31.78)
E = 2.00909 (from previous part), V = 1, Arc Cos .85 = 31.78 deg

The unknown is (IX). You will get IX = 1.29364. From here I = 1.29364/1.7 (because X = 1.7). Next, I will use the Sine formula to solve for the delta angle:

IX/Sin delta = E/Sin 121.78

Delta is the only unknown and hence it can be solved.

Another question is Tutorial3 Q3.3 (b) (ii) (iii). The given answer is using S=VI* to calculate the reactive power. But if I'm using Q=VE[cos(power angle)-V^2]/X,I cannot get the answer. For Qg, I have Qg=V2E2cos(power angle2)-V2^2/X)=(0.9892x1.2x 0.8974xcos48.46/1.45-0.9898^2/1.45)=-0.1877pu (the given answer is -0.1697pu).
Your power angle is incorrect. The power angle for use in Qg should be the difference between the power angle2 and the V2 phase angle, i.e. 48.46 deg – 1.854 deg = 46.606 deg. The reason is because 48.46 deg is meant for power transfer to V, the infinite bus and not V2, the generator bus terminal.

and Qload=VE2cos(power angle2)/(Xs+Xtr)-V^2/(Xs+Xtr)=-0.1893pu(given ans is -0.1887pu).
The answer is acceptable and the concept for this part is correct.

Why is that so? Is this method wrong?
Please see the explanation given above.

In general, for generator connecting in parallel, is it acceptable to generate MW beyond the total system loads, i.e. Pload < PG1 + PG2? My guess is 'no'.
In our analysis of parallel operation of generators, we assume that there are no losses when MW is transferred from generators to loads. Your guess is correct. It is not possible to have total generation > Pload under steady-state condition.

You could have generation < Pload **slightly** for a couple seconds but the system frequency will fall below 50Hz. After the governors have acted on it, the throttle/valve openings will be adjusted (will open wider) and the system frequency will be brought back to its normal value of 50 Hz.

I have some problem in one of the practice exercises in EE3015 lecture notes on Synchronous Machines. (p 99, Exercise 15.) Can you enlighten me on the approach?
You need to make use of the fact that each generator supplies full load of 30 MW at 50 Hz. This means that fsys = 50 Hz and PG1 = PG2 = 30 MW. From here, you substitute them back into PG1 = 20 (fnl1 – fsys) to obtain fnl1. Likewise, do the same for G2 and you obtain fnl2. After that you need to set up another system equation of PL = 38 MW = PG1 + PG2 and solve for the new fsys using fnl1 and fnl2 that you have obtained earlier.

I have tried solving the above using the actual values. I am unable to get the correct answer for the armature current. Attached is the solution of my working steps. Could you point out my mistake?

$P = \frac{VE}{X} \sin\delta$

Q 1(ii) alternate method using ~~the~~ actual values.

Max power at $\delta = 90^\circ$

$\therefore P_{max} = \frac{10 \times 13 \cdot 4}{5} \times 3$ → multiply by 3 to get total power. 1st term variables are per phase value.

$= 80 \cdot 4 \text{ MW}$

$Q = \frac{VE}{X} \cos 90^\circ - \frac{V^2}{X}$

$= -\frac{V^2}{X}$

$= \frac{-(10)^2}{5}$

$= -20 \text{ MVAr}$

$Q_{total} = -20 \times 3$

$= -60 \text{ MVAr}$

$S = 80 \cdot 4 - j60$

$= 100 \cdot 3203 \angle -36 \cdot 73^\circ \text{ MVA}$

$S = VI^*$

$I^* = \frac{100 \cdot 3203 \angle -36 \cdot 73^\circ}{10 \times \sqrt{3} \angle 0^\circ} = 5 \cdot 792 \angle -36 \cdot 73^\circ \text{ kA}$

You made a small mistake in your last step of Ia calculation. You forgot SQRT(3) in your 3-phase complex power equation. SQRT(3) is needed when you engage actual line voltage and line current in your S formula, i.e. S = SQRT(3) x Vl and Ia*.

If you use phase voltage and phase current (= line current for Y), then you need to multiply (Vp x Ia) by 3.

S = 3 x Vp x Ia*

Vp = 10 kV.