Power System Analysis

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Lecture - 57

Power System Stability (Contd.)

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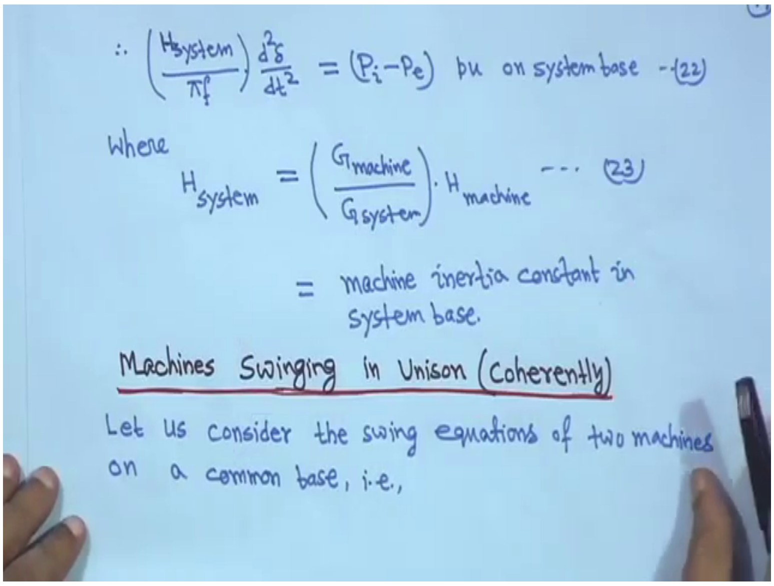

$$\therefore \left(\frac{H_{system}}{\pi f}\right)\frac{d^2\delta}{dt^2} = (P_i - P_e) \text{ pu on system base} \quad \text{—(22)}$$

Where

$$H_{system} = \left(\frac{G_{machine}}{G_{system}}\right) \cdot H_{machine} \quad \text{--- (23)}$$

= machine inertia constant in system base.

Machines Swinging in Unison (Coherently)

Let us consider the swing equations of two machines on a common base, i.e.,

So, now the machines actually swinging in unison that is coherently I told you. So, let us consider the swing equations of 2 machines on a common base will consider only 2 machine case.

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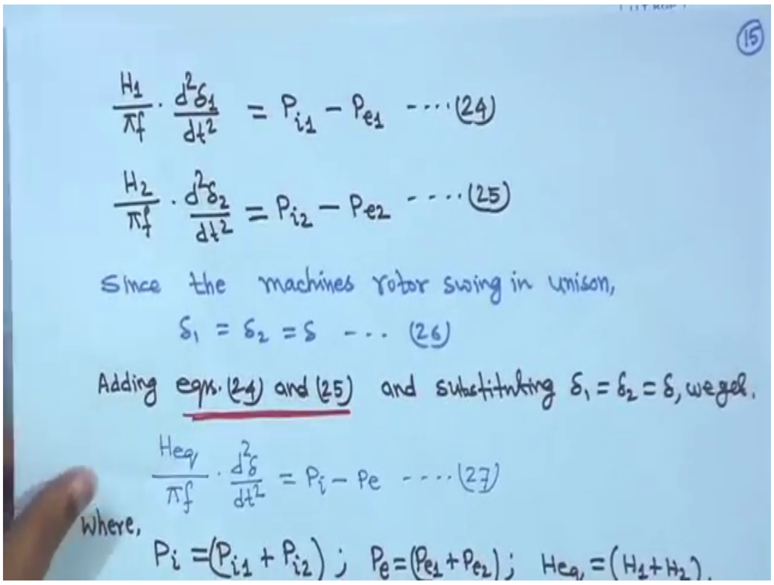

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$$\frac{H_1}{\pi f} \cdot \frac{d^2\delta_1}{dt^2} = P_{i1} - P_{e1} \quad \cdots (24)$$

$$\frac{H_2}{\pi f} \cdot \frac{d^2\delta_2}{dt^2} = P_{i2} - P_{e2} \quad \cdots (25)$$

Since the machines rotor swing in unison,

$$\delta_1 = \delta_2 = \delta \quad \cdots (26)$$

Adding eqn. (24) and (25) and substituting $\delta_1 = \delta_2 = \delta$, we get,

$$\frac{H_{eq}}{\pi f} \cdot \frac{d^2\delta}{dt^2} = P_i - P_e \quad \cdots (27)$$

Where, $P_i = (P_{i1} + P_{i2})$; $P_e = (P_{e1} + P_{e2})$; $H_{eq} = (H_1 + H_2)$.

So, for first one you can write H 1 up on pi f into d square delta 1 d t square is equal to P i 1 minus P e 1. This is equation 24 for the first machine. Now for the second machine, you can write H 2 up on pi f into d square delta 2 d t square is equal to P i 2 minus P e 2 that is equation 25. Since the machine rotor swing in unison; that means, I told you that there in coherent group; that means, their increase or decrease of the speed remains same I mean same, we can take them delta 1 is equal to delta 2 is equal to delta this is equation 26. So, if you add this equation 24 and 25. So, and substituting delta one is equal to delta 2 into delta will get you add and substitute delta 1 is equal to delta 2 is equal to delta, then you will get H e q divided by pi f into d square delta d t square is equal to P i minus P e; this is equation 27; that means, where P i is equal to P i 1 plus P i 2 P e is equal to P e 1 plus P e 2 and H e q actually is equal to H 1 plus H 2.

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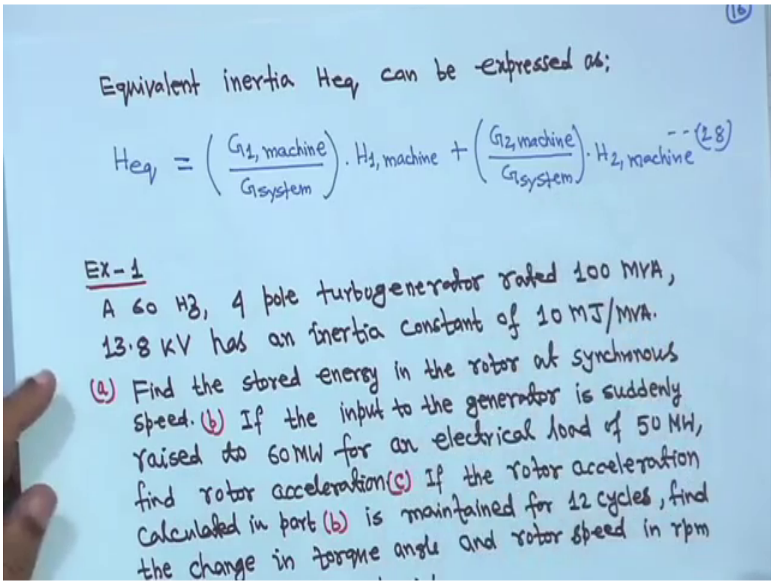

Equivalent inertia H_{eq} can be expressed as;

$$H_{eq} = \left(\frac{G_{1,machine}}{G_{system}}\right) \cdot H_{1,machine} + \left(\frac{G_{2,machine}}{G_{system}}\right) \cdot H_{2,machine} \quad --(28)$$

EX-1

A 60 Hz, 4 pole turbogenerator rated 100 MVA, 13.8 kV has an inertia constant of 10 MJ/MVA. (a) Find the stored energy in the rotor at synchronous speed. (b) If the input to the generator is suddenly raised to 60 MW for an electrical load of 50 MW, find rotor acceleration (c) If the rotor acceleration calculated in part (b) is maintained for 12 cycles, find the change in torque angle and rotor speed in rpm

Now, generally that H e q actually in general it will be G 1 machine into H 1 machine divided by G system plus G 2 machine into H 2 machine by G system that is the H actually in general in general.

If you have G 1 H 1, then you have your this is machine rating and inertia for second machine you have G 2 H 2 and third machine you have G 3 H 3 and so on, then G 1 H 1 plus G 2 H 2 plus make it general G n H n divided by your system base G system and that is actually H e q. So, H e q actually G 1 H 1 plus G 2 H 2 up to G n H n divided by G system. So, similarly here also we are putting the term machine actually here also in case G 1 H 1 plus G 2 H 2, right, divided by the G system.

So, this is the H equivalent, but if you take if for example, if G 1 machine G 2 machine and G system if all the values are same then basically it will be H 1 plus H 2; that means, when for 2 machine when they connected it parallel, right. So, their inertia should be added if they have equal rating otherwise this way you have to convert. So, now, we will come to the example. So, say the first example a 60 hertz 4 pole turbo generator rated 100 MVA; 13.8 kV has an inertia constant of 10 mega joule per MVA, you have to find out what a find the stored energy in the rotor at synchronous speed b, if the input to the generator is suddenly raised to 60 megawatt for an electrical load of 50 megawatt.

And find the rotor acceleration and c if the rotor acceleration calculated in part b. I mean see here in part b, here is maintained for 12 cycles, find the change in torque angle and the rotor speed in r p m at the end of this period, this is the problem you have to find out. So, that how will do this. So, part a; so, stored energy we know that G into H G is given 100 MVA H is 10 mega joule per MVA, it is given 10 mega joule per MVA, it is given and H is 100 MVA it is given; that means, stored energy 100 into 10. So, 1000 mega joule now in b, if the input to the generator is suddenly raised to 60 megawatt for an electrical load of 50 megawatt, find the rotor acceleration. Now accelerating power P a is equal to P i minus P e. So, electrical power P e is 50 megawatt and P i is that your what you call that that if the input to the generator is suddenly raised to 60 megawatt to an electrical load that is P i is 60 megawatt input. So, it is 60 minus 50 megawatt that is 10 megawatt.

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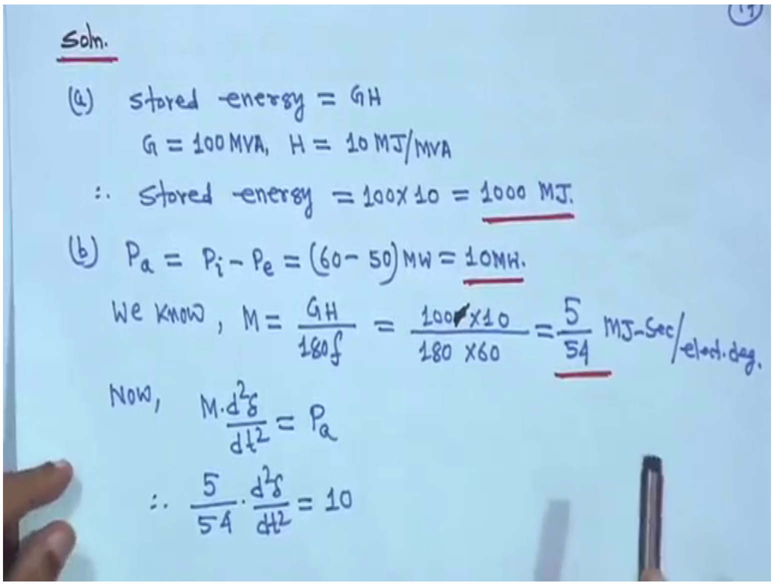

Soln.

(a) stored energy = GH

$G = 100\,\text{MVA}, \quad H = 10\,\text{MJ/MVA}$

$\therefore$ Stored energy $= 100 \times 10 = \underline{1000\,\text{MJ}}$.

(b) $P_a = P_i - P_e = (60 - 50)\,\text{MW} = \underline{10\,\text{MW}}$.

We know, $M = \dfrac{GH}{180f} = \dfrac{100 \times 10}{180 \times 60} = \underline{\dfrac{5}{54}}$ MJ-Sec/elect.deg.

Now, $M \cdot \dfrac{d^2\delta}{dt^2} = P_a$

$\therefore \dfrac{5}{54} \cdot \dfrac{d^2\delta}{dt^2} = 10$

So, accelerating power actually 10 megawatt; now we know M is equal to G H up on 100 80 f that is we are putting mega joule second per electrical degree. So, G H is equal to 1000 into your 10; your one it is actually 100 here, it is 1 here, H G is actually 100; I have made a mistake it is 100 into 10, but this answer is correct 100 into 10 divided by 180 into 60 that is 5 by 54 that is mega joule second per electrical degree.

Now, this M is known. Now you know that M into d square delta up on d t square is equal to accelerating power P a therefore, 5 by 54 into d square delta d t square is equal to 10 so; that means, that means d square delta d t square is equal to 10 into 54 by 508 electrical degree per second square this is the acceleration this is the acceleration.

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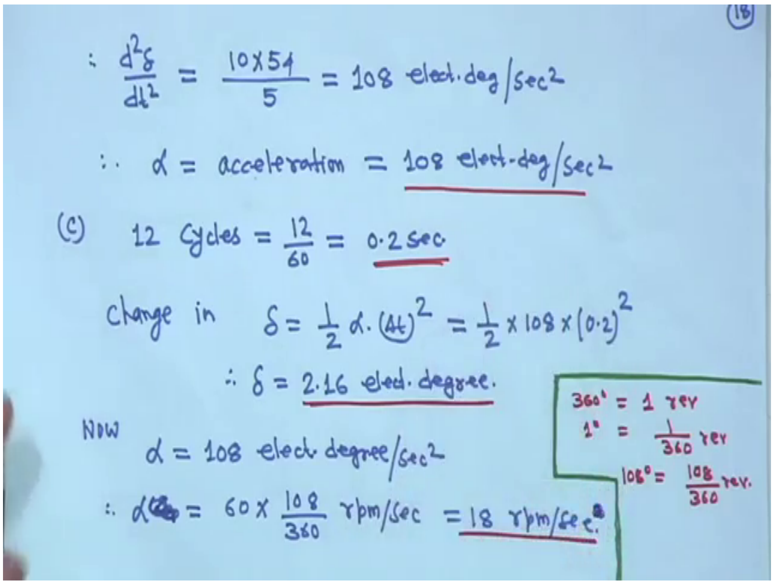

(18)

$\therefore \frac{d^2\delta}{dt^2} = \frac{10 \times 54}{5} = 108$ elect.deg/sec^2

$\therefore \alpha =$ acceleration $= 108$ elect-deg/sec^2

(c) 12 Cycles $= \frac{12}{60} = 0.2$ sec

Change in $\delta = \frac{1}{2}\alpha \cdot (\Delta t)^2 = \frac{1}{2} \times 108 \times (0.2)^2$

$\therefore \delta = 2.16$ elect. degree.

Now $\alpha = 108$ elect degree/sec^2

$\therefore \alpha = 60 \times \frac{108}{360}$ rpm/sec $= 18$ rpm/sec.

$360^\circ = 1$ rev

$1^\circ = \frac{1}{360}$ rev

$108^\circ = \frac{108}{360}$ rev.

So, 108 electrical degree per second you can d square delta by d t actually acceleration. So, alpha is equal to acceleration say alpha we define the acceleration is equal to 108 electrical degree per second square. Now part c it is mentioned that if the rotor acceleration calculated, in part b is maintained for 12 cycles find the change in torque angle and the rotor speed in r p m at the end of this period. So, 12 cycles means that is the 60 it your 60 hertz system it is 60 hertz system.

So, 12 cycles means 12 by 60 is equal to 0.2 second. So, change in delta is equal to half alpha into delta t square that is half that a acceleration into delta t square. So, half alpha is equal to your 108 electrical degree per second square into delta t square 0.2 square. So, delta actually 2.16 electrical degree that is the change in the; it has been asked now that your find the change in torque angle. So, this is the change in torque angle. Now this alpha is equal to 108 electrical degree per seconds square this one; we have to convert it to r p m revolution per minute per second the acceleration; how will do it.

Look it is a simple arithmetic 360 degree is equal to 1 revolution, 1 degree is equal to 1 up on 360 revolution and 108 degree that is whatever here is equal to 108 by 360 revolution, but from where we got this r p m per second. So, that is your; this one that your it is given know 108 electrical degree into second square. So, when you write like this it is multiplied by 60; that means, it is it is written know one up on second square. So, this one you can make it one up on second into second. So, this one second right this is your what you call 60 second is equal to one minute therefore, 1 second is equal to 1 by this simply arithmetic this, right.

So, because of this 1 second square that is second square that is second into second. So, that is; that means, second is equal to that one second is equal to you put if you put 1 up on 60 in the denominator then 60 will go up, 60 into 108 up on 360 r p m per second. So, this way we define alpha is equal to your 18 r p m per second, if you simplify it will be 18 r p m per second because we have to find out that it is given know and the rotor speed in r p m at the end of this period. So, this way we have to change the unit that alpha unit that will be r p m per second you make it. So, 18 r p m per second I mean this way this way you have to make it if you do. So, if you do. So, I one second I hope this conversion you have understood right that how we have made this one.

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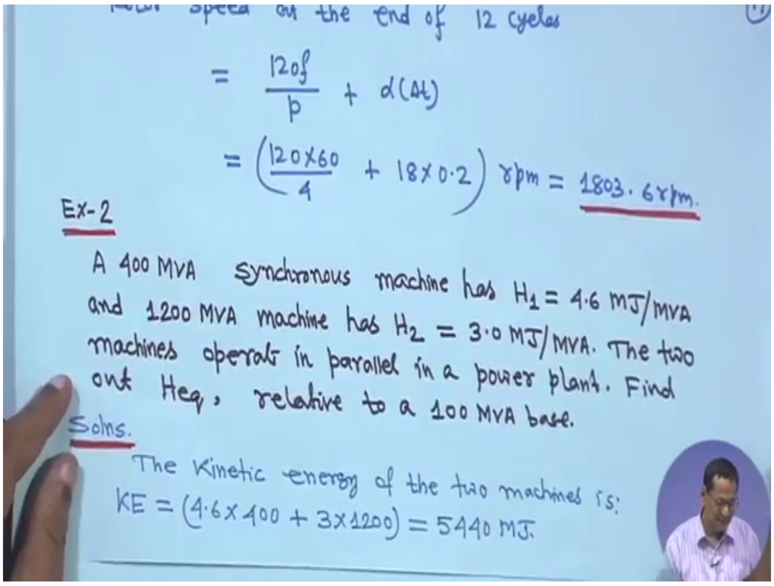

speed at the end of 12 cycles

$$= \frac{120f}{P} + \alpha(\Delta t)$$

$$= \left(\frac{120\times60}{4} + 18\times0.2\right) \text{rpm} = \underline{1803.6 \text{ rpm}}.$$

Ex-2

A 400 MVA synchronous machine has $H_1 = 4.6$ MJ/MVA and 1200 MVA machine has $H_2 = 3.0$ MJ/MVA. The two machines operate in parallel in a power plant. Find out H_{eq}, relative to a 100 MVA base.

Solns.

The Kinetic energy of the two machines is:

$KE = (4.6\times400 + 3\times1200) = 5440$ MJ.

Now, therefore, rotor speed at the end of your 12 cycles actually it is 120 f by P plus alpha into delta t. So, it is 120 into 60 by 4 plus 18 into 0.2 that is 1803.6 r p m, right and that is why we make this unit because it is alpha delta t that is why 18 r p m per second and that is why if you it is r p m per second. So, second second you cancel. So, unit will be your r p m and this is 120 f by P; r p m you know and this is 1803.6 r p m. This is the answer. So, little bit to be careful for your transforming the unit in the you know such that things will be alright next is that example 2 suppose a 400 MVA synchronous machine it is given H 1 is equal to 4.6 mega joule per MVA and 1200 MVA machine has

H 2 is equal to 3.0 mega joule per MVA the 2 machines operate in parallel in a power plant you have to find out H e q relative to a 100 MVA base that is system base. This is 100. So, the kinetic energy of the 2 machine is that k e is equal to that is your H 1 and G 1 H 1 this is your G 1 400 and H 14.6; 4.6 into 400 H 1 is given plus your this H 2 is 3 and your G 2 is 1200. So, total is 5440 mega joule.

So, this is your kinetic energy of the 2 machine now that formula was given that H e q is equal to G 1 machine into H 1 machine up on G system plus G 2 machine into H 2 machine up on G system.

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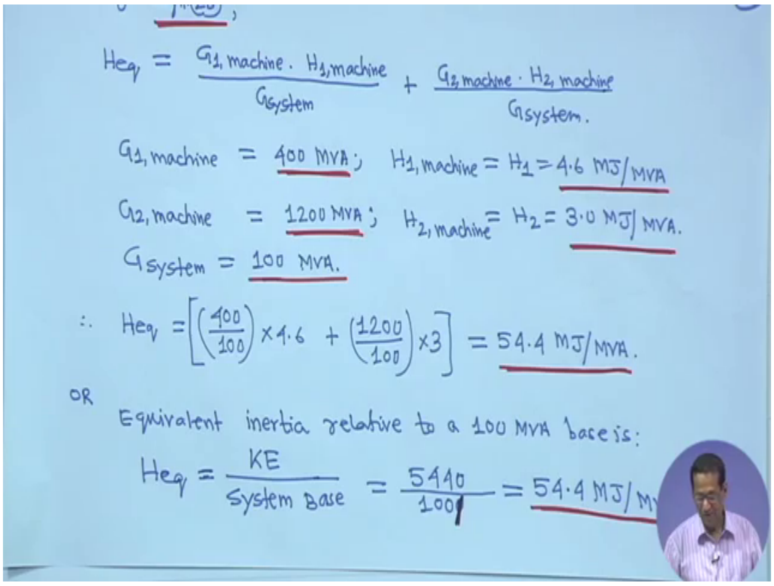

$$H_{eq} = \frac{G_{1,machine} \cdot H_{1,machine}}{G_{system}} + \frac{G_{2,machine} \cdot H_{2,machine}}{G_{system}}.$$

$G_{1,machine} = \underline{400\text{ MVA}}$; $H_{1,machine} = H_1 = \underline{4.6\text{ MJ/MVA}}$

$G_{2,machine} = \underline{1200\text{ MVA}}$; $H_{2,machine} = H_2 = \underline{3.0\text{ MJ/MVA}}.$

$G_{system} = \underline{100\text{ MVA}}.$

$$\therefore \quad H_{eq} = \left[\left(\frac{400}{100}\right) \times 4.6 + \left(\frac{1200}{100}\right) \times 3\right] = \underline{54.4\text{ MJ/MVA}}.$$

OR

Equivalent inertia relative to a 100 MVA base is:

$$H_{eq} = \frac{KE}{\text{System Base}} = \frac{5440}{1000} = \underline{54.4\text{ MJ/M}}$$

So, all the data given G 1 machine 400 MVA H 1 machine is equal to H 1 that is 4.6 mega joule per MVA then G 2 machine is equal to 1200 MVA and H 2 machine is equal to that is 3.0 mega joule per MVA and G system is 100 MVA that is on that you have to obtain, if you put everything together, it will become 54.4 mega joule per MVA. So, as a check equivalent inertia relative to a 100 MVA base that total kinetic energy was this one 5440. So, divide by system base. So, 5440 by your see your this thing what you call that 100 MVA base. So, 5440 here actually; it is 5440 divided by 100, I have by mistake I have made thousand it is 100. So, it is 54.4 mega joules per MVA as a check.

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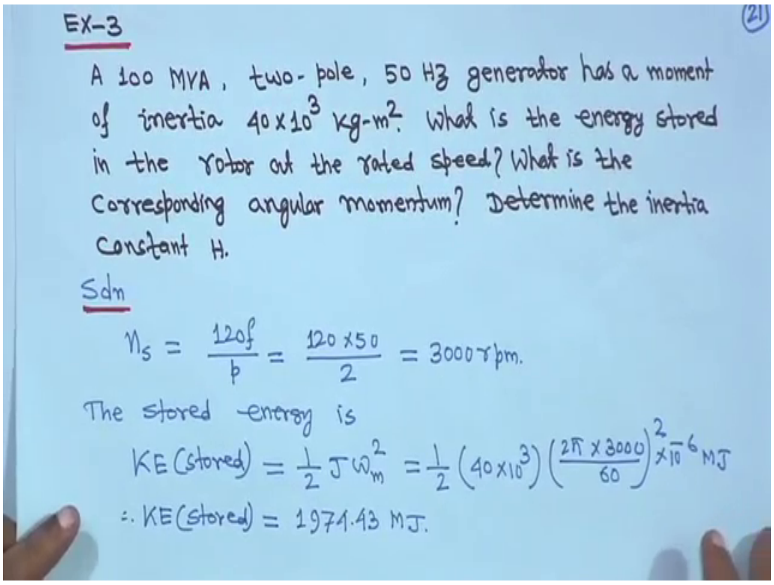

EX-3

A 100 MVA, two-pole, 50 Hz generator has a moment of inertia 40×10^3 kg-m^2. What is the energy stored in the rotor at the rated speed? What is the corresponding angular momentum? Determine the inertia constant H.

Soln

$$n_s = \frac{120f}{p} = \frac{120 \times 50}{2} = 3000 \text{ rpm.}$$

The stored energy is

$$KE(\text{stored}) = \frac{1}{2} J \omega_m^2 = \frac{1}{2}(40 \times 10^3)\left(\frac{2\pi \times 3000}{60}\right)^2 \times 10^{-6} \text{ MJ}$$

$$\therefore KE(\text{stored}) = 1971.43 \text{ MJ.}$$

So, once again several times I have made repetition that all this all this calculations actually I have done by me. So, if you find any calculation mistakes or any writing error anything I will appreciate if you let me know all this. So, example 3 that an 100 MVA 2 pole 50 hertz generator has a moment of inertia 40 into 10 to the power 3 kg meter square. So, what is the energy stored in the rotor at the rated speed and what is the your; what is the corresponding angular momentum and you have to find out determine the inertia constant H.

This 3 things you have to make it now synchronous speed n s is equal to 120 f by P is 2 poles, 3000 r p m. So, that will be actually your 3000 by 60 r p s right; revolution per second the stored energy kinetic half J omega M square it is a 2 pole machine. So, omega M electrical and omega M mechanical electrical radiant your and mechanical radiant both are same because it is a 2 pole machine therefore, kinetic energy half J omega square. So, half it is J 40 into 10 to the power 3 and this is your omega that is 2 pi your what you call that it is it is given r p m that is 3000 by 60 that will be r p s. So, 2 pi into 3000 by 60 square into 10 to the power minus 6 mega joule. So, that is actually coming 1974.43 mega joule similarly that kinetic energy H is equal to kinetic energy stored divided by the MVA base.

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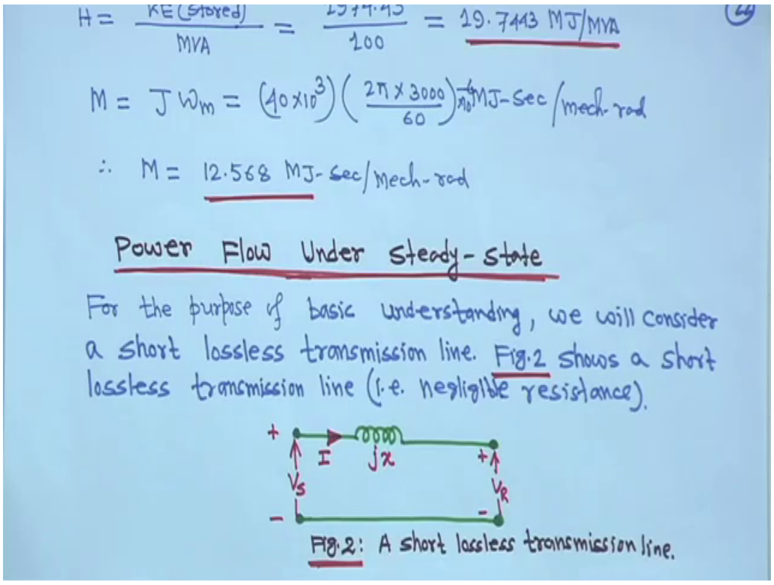

$$H = \frac{KE(\text{Stored})}{MVA} = \frac{1974.43}{100} = \underline{19.7443\ MJ/MVA}$$

$$M = J\omega_m = (40\times10^3)\left(\frac{2\pi\times3000}{60}\right)\times10^{-6}\ MJ\text{-}Sec/mech\text{-}rad$$

$$\therefore\ M = \underline{12.568}\ MJ\text{-}Sec/Mech\text{-}rad$$

Power Flow Under Steady-state

For the purpose of basic understanding, we will consider a short lossless transmission line. Fig.2 shows a short lossless transmission line (i.e. negligible resistance).

Fig.2: A short lossless transmission line.

So, that is 1974.43 divided by 100. So, it is 19.7443 mega joule per MVA therefore, M is equal to J into omega M; this we know earlier we have seen earlier also that is 40 into 10 to the power 3 into this omega M into 10 to the power minus 6, here 10 to the power minus 6 is there. So, that is mega joule second per mechanical radiant and it is M is equal to 12.568 mega joule per second mechanical it is by 2 pole machine. So, mechanical electrical and radiant it is same.

So, this is your; this small example, we have taken now let us come to the power flow under steady state condition. So, will take a short transmission line will assume that resistance is neglected. So, only your reactance is there for the transmission line. So, as resistance is neglected means the line is actually lossless line. So, for the purpose of basic understanding we will consider a short lossless transmission line and figure 2 is it is given that right and negligible resistance there is no resistance in the line for transmission line performance characteristic we have seen considering r, but here will not consider r; that means, sending end real power and receiving end real power both will same P s and P i will be same because resistance is not there.

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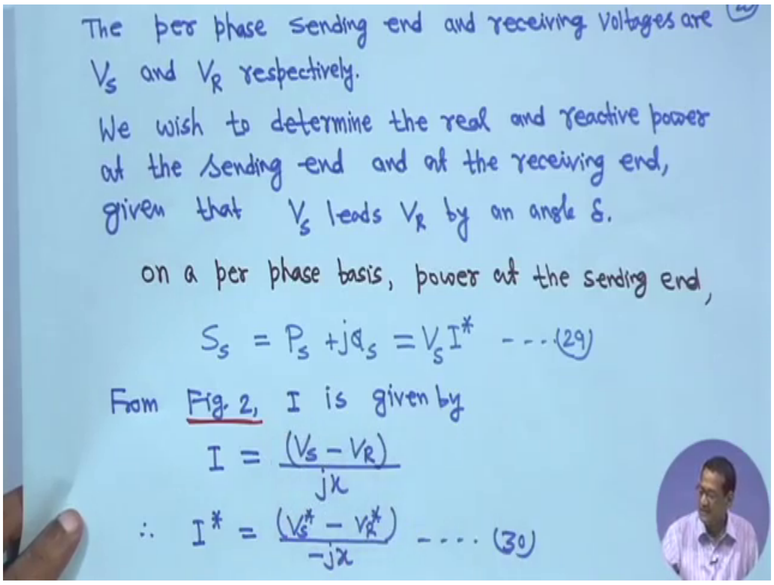

The per phase sending end and receiving voltages are V_S and V_R respectively.

We wish to determine the real and reactive power at the sending end and at the receiving end, given that V_s leads V_R by an angle δ.

on a per phase basis, power at the sending end,

$$S_s = P_s + jQ_s = V_s I^* \quad \text{---(29)}$$

From Fig. 2, I is given by

$$I = \frac{(V_s - V_R)}{jx}$$

$$\therefore \quad I^* = \frac{(V_s^* - V_R^*)}{-jx} \quad \text{----(30)}$$

So, the per phase sending end and receiving voltages are V S and V R respectively. So, we wish to determine the real and reactive power at the sending end and at the receiving end given that V S leads V R by an angle delta this condition we have to assume that V S actually sending end voltage leading receiving end voltage by an angle delta so on per phase basis power at the sending end. So, your we know; this previously we have studied for load flow studies also that sending end power P s plus JQSs is equal to P S plus JQS is equal to V S I conjugate. So, this is equation twenty nine now from figure 2 that I is given by I mean from figure this one I is equal to V S minus V R divided by J x.

So, I is equal to V S minus V R by J x and if you take conjugate I conjugate it will be V S conjugate minus V R conjugate divided by as a conjugate. So, J x will become minus J x. So, this is equation 30, so that here is actually V S leading V R by an angle delta.

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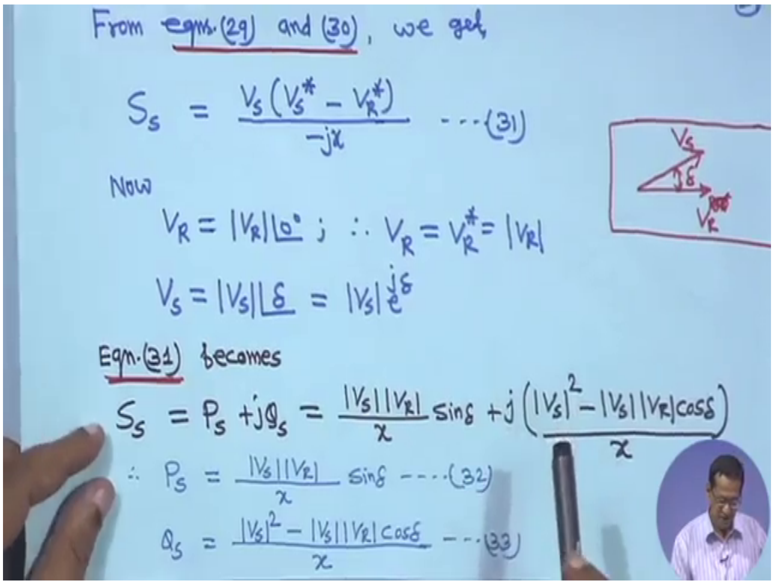

From eqns.(29) and (30), we get

$$S_s = \frac{V_s(V_s^* - V_R^*)}{-jx} \quad ---(31)$$

Now

$$V_R = |V_R|\angle 0^\circ \; ; \quad \therefore V_R = V_R^* = |V_R|$$

$$V_s = |V_s|\angle\delta = |V_s|e^{j\delta}$$

Eqn.(31) becomes

$$S_s = P_s + jQ_s = \frac{|V_s||V_R|}{x}\sin\delta + j\left(\frac{|V_s|^2 - |V_s||V_R|\cos\delta}{x}\right)$$

$$\therefore P_s = \frac{|V_s||V_R|}{x}\sin\delta \quad ----(32)$$

$$Q_s = \frac{|V_s|^2 - |V_s||V_R|\cos\delta}{x} \quad ---(33)$$

So, from equation twenty nine and thirty; that means, here this I conjugate you substitute here I conjugate you substitute here if you do. So, that S is equal to V S into V S conjugate minus V R conjugate divided by minus J x this is equation thirty one now V R is equal to magnitude V R angle 0 degree. So, V R is equal to V R conjugate also will be V R because angle is 0 degree V S is equal to magnitude V S angle delta is equal to magnitude V S e to the power J delta that what we write now all this things you substitute all this things you put it here if you do. So, then you and simplify you will get s s is equal to P s plus J q s is equal to magnitude V S magnitude V R up on x sin delta plus J in bracket magnitude V S square minus magnitude V S magnitude V R cosine delta up on x; that means, P s is equal to magnitude V S magnitude V R up on x sin delta this is equation thirty 2 and q s is equal to magnitude V S square minus magnitude V S V R into cosine delta up on x. So, this is your; what you call sending end power real power and reactive power.

Now, similarly this in a similar way if you do, so, means similar way if we do.

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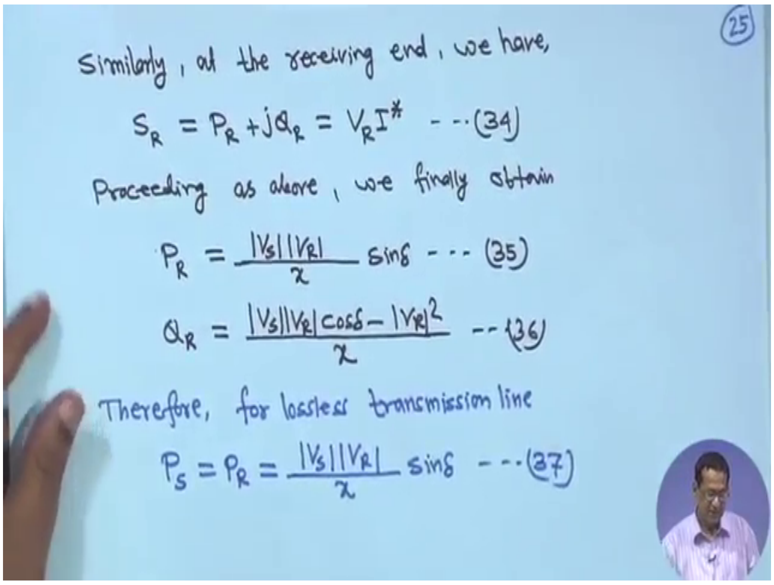

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Similarly, at the receiving end, we have,

$$S_R = P_R + jQ_R = V_R I^* \quad ---(34)$$

Proceeding as above, we finally obtain

$$P_R = \frac{|V_S||V_R|}{x}\sin\delta \quad ---(35)$$

$$Q_R = \frac{|V_S||V_R|\cos\delta - |V_R|^2}{x} \quad ---(36)$$

Therefore, for lossless transmission line

$$P_S = P_R = \frac{|V_S||V_R|}{x}\sin\delta \quad ---(37)$$

So, then S R similarly at the receiving end we have S R is equal to P r plus J Q R is equal to V R I conjugate similar way if we proceed you will get P r is equal to V S V R up on x sin delta and Q R you will get V S V R cos delta up on x sorry minus V R square up on x this is equation thirty six, but here our objective will be considering real power.

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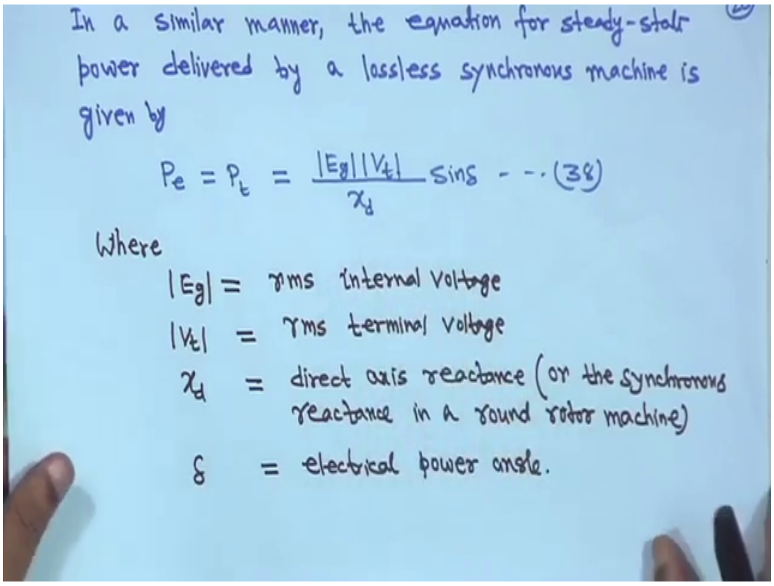

In a similar manner, the equation for steady-state power delivered by a lossless synchronous machine is given by

$$P_e = P_t = \frac{|E_g||V_t|}{x_d}\sin\delta \quad ---(38)$$

Where

$|E_g|$ = rms internal voltage

$|V_t|$ = rms terminal voltage

x_d = direct axis reactance (or the synchronous reactance in a round rotor machine)

δ = electrical power angle.

So, therefore, for lossless transmission line P S is equal to P R is equal to magnitude V S magnitude V R up on x sin delta. This is equation 37 in a similar manner, the equation for steady state steady state power delivered by a lossless synchronous machine also it can be given as P e is equal to say P t then magnitude e G then your magnitude V t up on x d sin delta this is equation 38 where magnitude e G is r M s internal voltage of the synchronous machine magnitude V t is the r M s terminal voltage magnitude, again of the synchronous machine and x d is equal to direct axis reactance in bracket I have written or the synchronous reactance in a round rotor machine and delta is equal to electrical power angle. So, P e is equal to P t is equal to magnitude e t e G magnitude V t up on x d sin delta.

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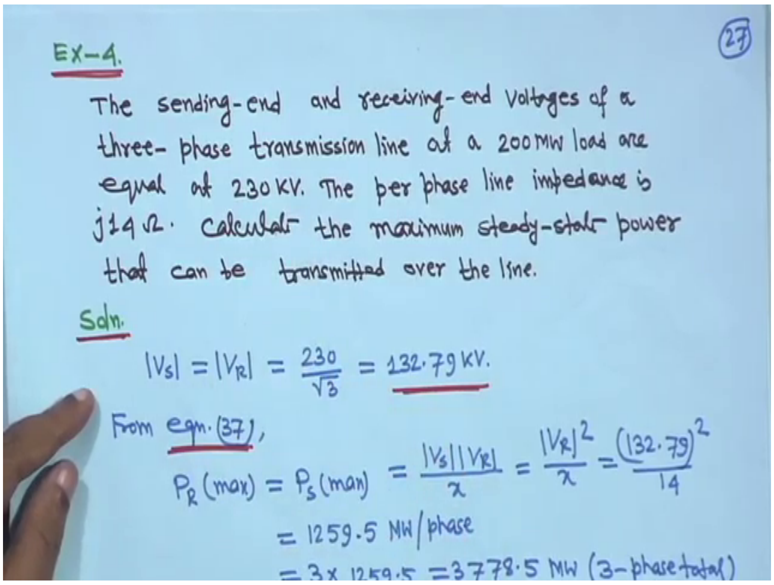

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EX-4.

The sending-end and receiving-end voltages of a three-phase transmission line at a 200 MW load are equal at 230 kV. The per phase line impedance is $j14\,\Omega$. Calculate the maximum steady-state power that can be transmitted over the line.

Soln.

$$|V_S| = |V_R| = \frac{230}{\sqrt{3}} = \underline{132.79\ \text{kV}}.$$

From eqn. (37),

$$P_R(\max) = P_S(\max) = \frac{|V_S||V_R|}{x} = \frac{|V_R|^2}{x} = \frac{(132.79)^2}{14}$$

$$= 1259.5\ \text{MW/phase}$$

$$= 3 \times 1259.5 = 3778.5\ \text{MW (3-phase total)}$$

Now, example your; what you call exam example 4. So, so the sending end and receiving end voltages of a 3 phase transmission line at a 2100 mega megawatt load are equal at 230 your at 230 kV; that means, sending and receiving end voltage of a 3 phase transmission line at a 200 megawatt load are equal at a 230 kV the per phase line impedance is J 14 ohm that is r is neglected reactance is taken calculate the maximum steady state power that can be transmitted over the line. So, magnitude V S V R which you earlier we have discussed that will go for per phase basic analysis. So, magnitude V S is equal to magnitude V R is equal to 230 up on root 3 that is 132.79 kV. Now from equation 37 P r max is equal to P s max is equal to V S V R up on x because in that case sin delta is equal to one that delta is equal to 90 degree and V S is equal to V R magnitude; that means, V R square up on x that is 132.79 square up on 14. So, that is actually 1259.5 megawatt per phase. So, if it is a 3 phase this is 3 phase it will be 3 into 12 1259.5 is equal to 3778.5 megawatt that is 3 phase total.

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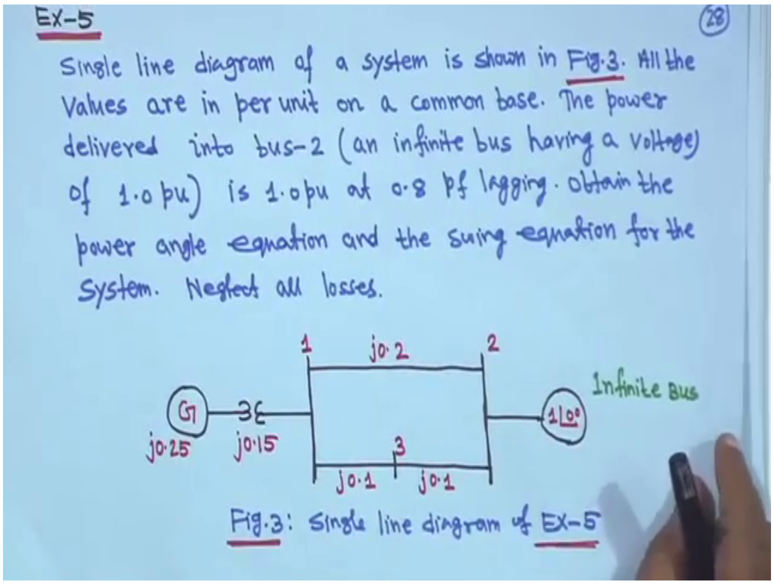

EX-5

Single line diagram of a system is shown in Fig.3. All the Values are in per unit on a common base. The power delivered into bus-2 (an infinite bus having a voltage of 1.0 pu) is 1.0 pu at 0.8 pf lagging. Obtain the power angle equation and the swing equation for the system. Neglect all losses.

Fig.3: Single line diagram of EX-5

So, there this example is a simple example simple example next you take the single line diagram of this figure of the it is given here say the single line diagram of a system is shown in figure 3 that is this is your figure 3 all the values are in per unit on a common base the power delivered into bus 2, this is bus 2 and infinite bus having a voltage of 1 P u, this is infinite bus voltage 1 angle, 0 is given and your what you call bus 2 is 1 P u that is that power delivered into bus 2 is 1 per unit at 0.8 power factor lagging obtain the power angle equation and the swing equation for the system neglect all losses. So, this is a diagram is given this is a generator and this is infinite bus now before solving this problem let us try to understand what is infinite bus generally we know that infinite bus means voltage magnitude and its angle both will remain constant, but what does it mean for infinite bus.

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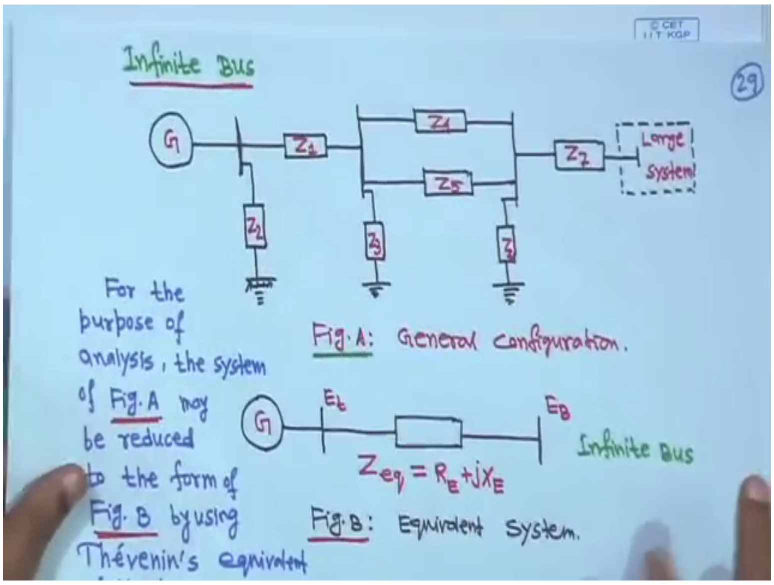

Infinite Bus

Fig. A: General configuration.

For the purpose of analysis, the system of Fig. A may be reduced to the form of Fig. B by using Thévenin's equivalent

$Z_{eq} = R_E + jX_E$

Fig. B: Equivalent System.

So, first will try to see what is infinite bus and then will try to solve this problem then things will be understandable for all of us right. So, for example, the first let us define that how we define infinite bus. So, this is a generator is there and this is a power system network it is given like this; this is a transmission network is given this impedance is Z 1, Z 2, Z 3, Z 4, Z 5 your Z 6, Z 7 and it is a large system here with this whole transmission network is connected with a very large system.

And this is a diagram I have taken and this is a double circuit line. So, this is I made marked it as a figure a; the general configuration now for the system for the system for the purpose of analysis the system of figure a look there is no link between the this, problem with your this diagram this is a take I have taken for purpose of explanation. So, for the purpose of analysis the system of figure a may be reduced to the form of figure b this is the form of figure b this is this is equivalent has been made by using Thevenin equivalent of the transmission network external to the generator right external to the machine and the adjacent transmission line.

So, all this things and equivalent your Thevenin equivalent had been made and the. So, this is generator will be there this is the terminal voltage e t is there and this is Z e q is equal to r e plus J x e this is the Thevenin equivalent we have made it suppose it is for you have made it and this large system has been represented by a bus say it is given e b that capital e suffix b and this is your we call this is infinite bus now and this is a large system it is a large system.

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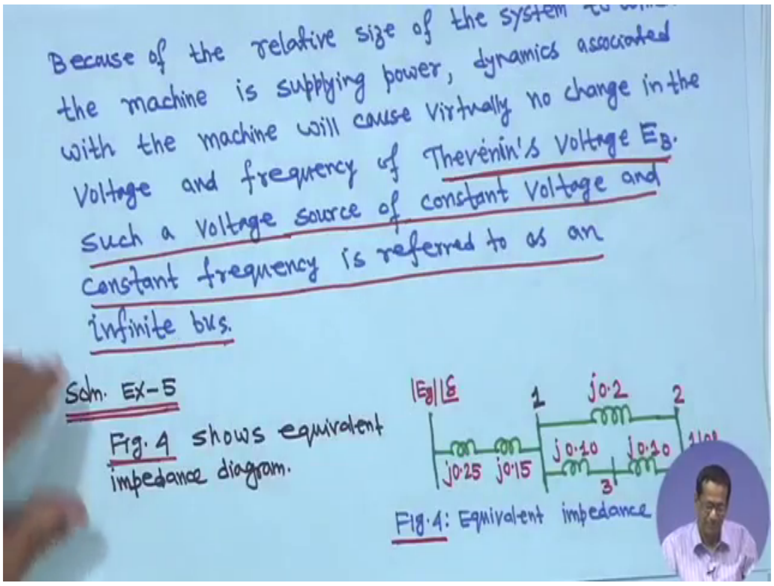

Because of the relative size of the system to
the machine is supplying power, dynamics associated
with the machine will cause virtually no change in the
Voltage and frequency of Thevenin's Voltage E_B.
Such a Voltage source of constant Voltage and
constant frequency is referred to as an
infinite bus.

Soln. Ex-5

Fig. 4 shows equivalent impedance diagram.

Fig. 4: Equivalent impedance

So, because of the relative size of the system I mean this is a large system this is a large system. So, because of the relative size of the system to which the machine is supplying power; that means, this is a machine, it is supplying power to a very large system it is supplying a power to a very large system.

Right, the machine is dynamics associated with the machine will cause virtually no change in the voltage and frequency of Thevenin’s voltage e b; that means, compare to this system that dynamics associated with the machine actually whatever may be the changes the dynamics associated with the machine it will cause virtually no change in the voltage and frequency of Thevenin’s voltage e b; that means, this system is a large compare to that this generator is small relatively small therefore, dynamics associated with that if any changes is there it will not cause any change to this bus; this voltage e b magnitude and its angle; it will remain unchanged and such a such a voltage source of constant voltage and constant frequency is referred to as an infinite bus.

So, this is your definition of infinite bus. So, I repeat that I mean concept should be clear, suppose we have a generator and we have a heavy large system. So, you make one Thevenin equivalent right external to the generator there is whole transmission Thevenin equivalent external to the generator external to the generator and that is Z e q is equal to r e plus J x e and this bus bar voltage, here we make it as e b that is the infinite bus voltage we call and next is that dynamics of this system, I mean this system or this one compared to this one actually this is a very large system compared to the shift; that is a not; it is not that large it is small one if any dynamics change associated with the machine it will never affect this voltage and its frequency; your voltage magnitude and frequency

That is why this your; the Thevenin’s voltage such a voltage source of constant voltage and constant frequency is referred to as an infinite bus. So, that is the sometimes we call what is infinite bus. So, this should be the definition of the infinite bus basically it is the; what you call is a Thevenin voltage e b and system is. So, large that it dynamics cannot affect the voltage this voltage magnitude and its angle. So, that is the definition of the infinite bus. So, because in this problem that infinite bus is there that is why I thought I should explain you and most of the numerical this that you always take that your one angle 0.

So, this is bus 3 is given. So, this problem is generator thing is given J your reactance is given J 0.25 transformer is J 0.15 and this is line one to 2.2 and this 3; I have made another bus bar is there, but we dint we and your this side is J 0.1 J 0 point same line, but total is 0.2. So, if you now; if you your what you call make this equivalent circuit diagram there is a generator voltage this generator voltage we can write magnitude e G angle delta and this is J 2.5, sorry, 0.25 and J 0.5. So, J 0.25 J 0.15, right and this one to 2 it is J 0.2 and here it is 1 3 2 J 0.1; J 0.1 and this is infinite bus voltage, right. So, we are making it as a 1 angle 0. So, this is equivalent impedance diagram of this network.

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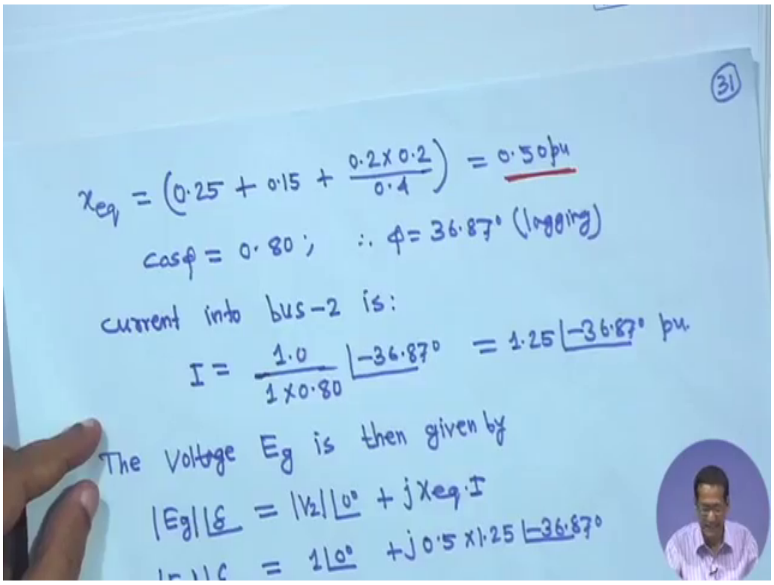

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$$x_{eq} = \left(0.25 + 0.15 + \frac{0.2 \times 0.2}{0.4}\right) = \underline{0.50\,pu}$$

$\cos\phi = 0.80$; $\therefore \phi = 36.87°$ (lagging)

current into bus-2 is:

$$I = \frac{1.0}{1 \times 0.80} \angle{-36.87°} = 1.25 \angle{-36.87°}\ pu.$$

The Voltage E_g is then given by

$$|E_g| \angle \delta = |V_2| \angle 0° + jX_{eq} \cdot I$$

$$= 1 \angle 0° + j0.5 \times 1.25 \angle{-36.87°}$$

So, this is your; what you call the equivalent from this one we have to solve that how we can do it. So, so x e q can be taken as your this 2 you add and this 2 are in parallel. So, 0.1, 0.1, 0.23; actually I have marked intentionally, but no fault nothing is created it is a double circuit line, but one more bus bar is created here. So, 0.1, 0.1, 0.2; so, 0.2 and 0.1 is parallel. So, your x e q will be 0.25 plus 0.15 plus 0.2 into 0.2 up on 0.2 plus 0.2, 0.4. So, 0.50 per unit and power factor is given 0.8 lagging. So, phi is equal to 36.87 degree lagging.

Now current into bus 2 actually if you read the problem if you read the problem that the power delivered into bus 2 an infinite volt bus voltage is given one per unit angle 0 is 1 is 1 per unit; that means, power delivered into bus 2 is one per unit and infinite bus voltage is also one angle sorry one angle 0 per unit and point eight power factor lagging; that means, current at bus 2 will be V I cos phi. So, I is equal to 1; this is input power, right and this is your infinite bus voltage and into 0.8 the power factor is given. So, V I cos phi is equal to 1; everything is per angle, but lagging. So, minus 36.87 that is your 1.25 angle minus 36.87 degree.

Thank you will come.