Lecture - 06
Passive Shunt and Series Compensations (contd.)

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Welcome to the lecture on this Passive Compensation. We were discussing the numerical examples. [FL] This is the 6th numerical examples on a three-phase, three-wire delta connected balance load of Z L equal to 3.0 per unit plus 1.0 per unit has an input ac line voltage of 415 volt, 50 Hertz, AC supply and a base impedance of 8.25 ohm per phase.

So, it is to be realized as a unity power factor load on the ac supply system using shunt connected lossless passive element. And calculate the supply line current, compensator

current, the value of compensating element its kVA rating, and equivalent per phase resistance of the compensated load.

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Schematic diagram and performance waveforms
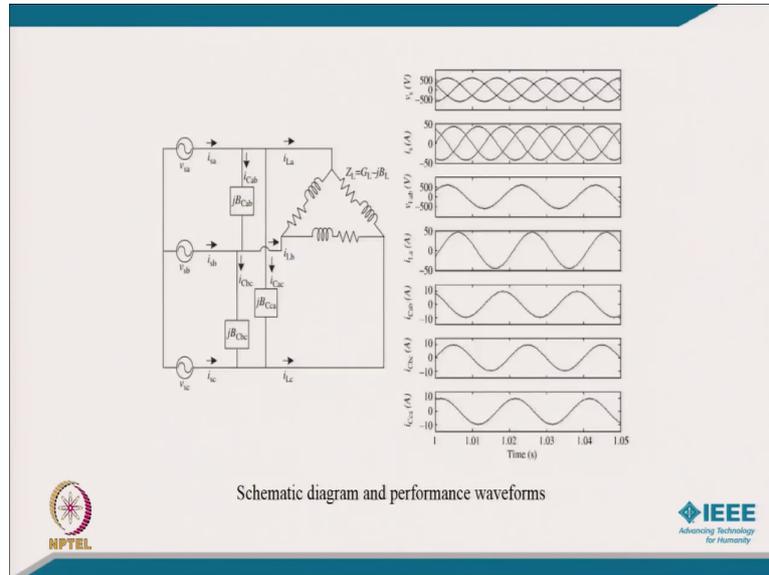
Well, this is the circuit I mean of the, this problem schematic diagram and perform waveform. [FL]We have a three-phase supply. And we have a, this typically a balanced load connected of reactive load across the three-phase line, and then we have a here the compensator. And these are the typical waveform after estimating then the after the designing of it like.

Solution: Given that, supply voltage, V_s = 415 V, frequency of supply, f = 50 Hz, three-phase load, Z_L = (3+j1) pu with base impedance of 4.15 ohms per phase.

The load resistance, R_L = 8.25*3.0 Ω =24.75 Ω. The load reactance, X_L = 8.25*1Ω = 8.25Ω.

The load admittance, Y_L =1/Z_L = G_L − jB_L = (0.0364-j0.0121) mhos.

(a) The supply current after the compensation, I_s = ($\sqrt{3}$)$V_s G_L$ = 26.138 A.

Because of balanced and symmetrical operation, I_{sa} = I_{sb} = I_{sc} = I_s = 26.138 A.

For unity power factor operation the compensator, shunt capacitors are connected in parallel to all load branches. For UPF operation B_L = − B_c = 0.0121.

(b) The compensator phase current, I_C = V_s*B_c = 415*0.0121= 5.03 A. All compensator branches share equal compensator currents.

[FL]Let us discuss that given a supply voltage of 415 volt at 50 Hertz three-phase load of 3 plus 1 per unit j per unit with base impedance of 4.15 ohm. [FL] From this we can calculate the load resistance by utilizing this typically this four point into 3 this become 24.75, and load reactance typically of 4.15 into 1 that is 8.2.

[FL] The load admittance Y L equal to 1 upon Z L, and G L minus j B L [FL]it becomes like 0.0364 minus j 0.12 mhos.[FL]Supply current after the compensation will be I s root 3 V S G L [FL] it will be 26.13 ampere. Because of the balance symmetrical operation, the current in all the three-phase after compensation will be 26.13 ampere ohm.

For unity power factor operation of the compensator, shunt compensator are to be connected in parallel to all the load branches. For UPF operation [FL] B L should be equal to minus B c and that is 0.0121 mho. And compensator phase current will be that V S into B L [FL] here

the is connected across line to line because of delta connection [FL]it will be 415 into 0.0121 that comes 5.03 ampere. And all compensator branches share the equal compensator current right.

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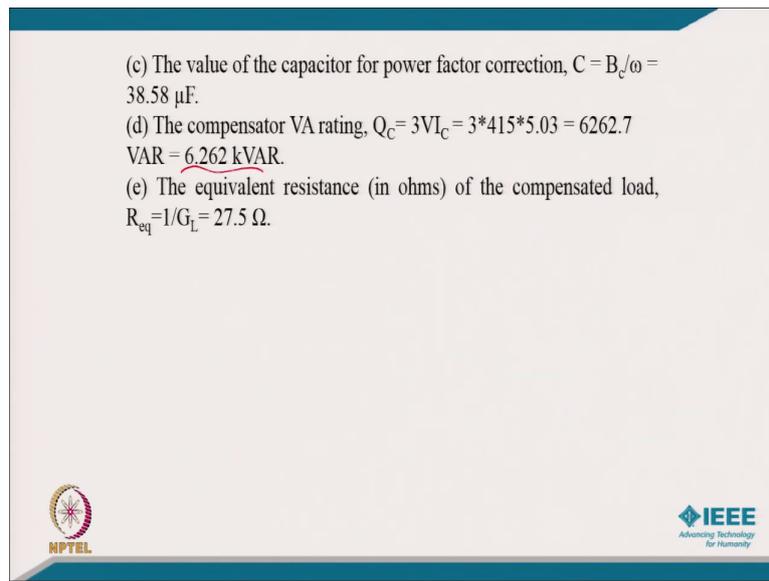
(c) The value of the capacitor for power factor correction, $C = B_c/\omega = 38.58 \, \mu F$.

(d) The compensator VA rating, $Q_C = 3VI_C = 3*415*5.03 = 6262.7$ VAR = 6.262 kVAR.

(e) The equivalent resistance (in ohms) of the compensated load, $R_{eq} = 1/G_L = 27.5 \, \Omega$.

[FL] The value of capacitor for power factor correction C equal to B c upon omega [FL] it come 38.58 micro Farad. And compensator VA rating you can call it is for the all three-phases, it comes like 3 V I c [FL] it will be 3 into 415 into 5.03[FL] it become 6267 VR it equivalent to like a 6.26 typically of VAR. The equivalent resistance of the compensator load is R equal 1 upon G L and that your 27.5 ohm.

Well, coming to the next problem, typically a problem number 7, a three-phase, three-wire, ac distribution system has a line voltage of 415 volt, 50 Hertz and feeder impedance of 2 ohm resistance and 2 ohm inductive reactance phase after which a balanced delta connected load of 24.24 plus j 18 ohms per phase is connected.

And calculate the voltage drop across the source impedance, voltage across the load. A shunt compensator consisting of a lossless passive element is used to raise the voltage as the same as the input voltage as shown in figure. Calculate the supply line current, compensator current, the value of compensator element, and its kVA rating.

Solution: Given that, the supply phase voltage, $V_s=415/\sqrt{3}$ V=239.6 V, frequency of the supply, f=50 Hz, delta connected load of $Z_L=(24+j18)$ ohms/phase. The source impedance is as, $Z_s = R_s+jX_s= (2+j2)$ Ω. The star equivalent of the load, $Z_{LY}= Z_L/3= (24+j18)/3$ ohms/phase= $(8+j6)$ ohms/phase.

Total impedance/phase, $Z_T= Z_S+ Z_{LY} = (10+j8)$ Ω = 12.806 Ω.

The load line current before compensation is as.

$I_{sold}=V_S/Z_T=239.6/12.806$ A=18.71A.

(a)The voltage drop across the source impedance before compensation is as,

$V_{zsold} = I_{sold}*Z_S = 52.919$ V.

(b) The voltage across the load before compensation is as,

$V_{zLold}=I_{sold}*Z_{LY}*\sqrt{3}=324.061$ V.

The load admittance, $Y_{LY}=G_{LY}+jB_{LY}=1/Z_{LY}=(0.08-j0.06)$ mhos.

The load power factor can be made unity by connecting a susceptance of

$B_{PF} =-B_{LY}=0.06$ mhos.

Coming to solution of this problem,[FL] given that the supply phase voltage is 415 by root 3 that is 239.6 volt, and frequency of supply of 50 Hertz, and delta connected load of Z L equal to 24 point j 18 ohms or phase. The source impedance is as R S plus j S 2 plus j 2 ohm. And the star equivalent of the load will be Z LY will be equal to Z L delta by 3 [FL] it become 24 point j 18 divide by 3 and that is comes 8, 8 plus j 6 ohm per phase.

The total impedance at the circuit equivalent star connection, I mean including the source impedance and equivalent star will be Z T equal to Z S plus Z LY that will be your 10 plus j 8, and that magnitude of you can call it of impedance is your 12.806 ohm. [FL] The load line current before compensation will be i V S upon Z T, and that is 230 that is a phase voltage 415 by root 3, 2 that is equivalent to 239.6 divided by 12.806 that is the impedance, and value comes off this 18.71 ampere.

And the average voltage drop across the source impedance after the compensation will be I S V S V Z S old equal to I S old into Z S, and that comes typically after multiplication of this it comes 52.919 volt. And voltage across the load before the compensation is your now V Z old as where I S old into Z LY by root into root 3[FL] it come 324.06 in place of 415.

[FL] You can call it like now because you see lagging power factor load and you have a source in reasonable source impedance or feeder impedance and that is the reason this voltage reduces from 415 to 324.061 volt.

[FL]Load and where the now we can convert the load admittance per phase, I mean as a load conductance in equivalent star G LY plus j B LY that is 1 upon Z LY, and it comes to equal to 0.06 minus j 0.06 mho. And the load power factor can be made unity by connecting a susceptance in parallel to this equivalent to that will be BPF for power factor correction minus B LY and will be 0.06 mho.

Let the susceptance of value B_{cv} mhos is to be connected in parallel to the load to raise the load voltage equal to the input voltage ($V_L = V_S$). The basic equation to regulate the load voltage equal to input voltage is as,

$$|V_L| = |V_s|/[\{(R_s + jX_s) + 1/(G_{LY} + jB_{cv})\}] | * |1/(G_{LY} + jB_{cv})| = |V_S|$$

Solving this equation, the value of B_V is as,

$$B_{cv} = [X_S \pm \{\sqrt{X_S^2 - (X_S^2 + R_S^2)(2R_S G_{LY} + R_S^2 G_{LY}^2 + X_S^2 G_{LY}^2)}\}]/(X_S^2 + R_S^2)$$

Substituting the values of $X_S = 2\ \Omega$, $R_S = 2\ \Omega$ and $G_{Ly} = 0.08$ mhos and considering "-" sign in "$\pm$", for lower value of the compensator, the value of B_{cv} is as, $B_{cv} = 0.123$ mhos.

The total susceptance for the power factor correction and voltage regulation is as, $B_T = B_{cv} + B_{PF} = 0.183$ mhos.

The supply line current is as,

$$|V_s|/[\{(R_s + jX_s) + 1/(G_{LY} + jB_{cv})\}] | = 239.6/|[\{(2+j2) + 1/(0.08 + j0.123)\}]|$$
$$= 35.152 A.$$

The susceptance to be connected line to line for power factor correction is $B_D = B_T/3 = 0.061$ mho

[FL] Let the susceptance of the value B is cv, mho is to be connected in parallel to the load to raise the voltage equal to the input voltage for voltage 0 voltage regulation V L equal to V S. And the basic equation to regulate the load voltage equal to the voltage is as V L magnitude should be equal to the V S magnitude.

And V L magnitude we can calculate of course by finding the current and then the multiplication of the your let us say load admittance, load impedance along with the compensator which we have already put it like [FL] that will be V S upon the total impedance I mean the source impedance plus the impedance of the load along with the your you can call it the compensator impedance multiplied the impedance of the load along with the compensator.

[FL]That solving this we will get B cv equal to X S plus minus under root X S square minus X S square R S square into 2 R S G LY R S square G L y square and X S square G LY square and divide by X S square R S square.

[FL] Substituting the value of X S equal to 2 R S equal to 2, and G LY 0.08, and considering minus sign in plus minus for lower value of the compensator the value of B cv is as B cv equal to 0.123 mho. And total susceptance for power factor correction and voltage regulation now is B T be will be equal to B cv plus B PF that the 0.183 mho.

And the now the supply line current will be keeping the value in this source impedance, and then total it comes like 239 point the putting the value of all these elements, it come 35.152 ampere. And to susceptance to be connected line to line for power factor correction that is B D equal to B T by 3 and that is a 0.061 mho.

After compensation load line to line voltage is V_{LL}=415 V.

(d) The compensator currents are $V_{LL}*B_D$ = 415*0.061 = 25.315 A.

(e) The value of the capacitor for power factor correction and voltage regulation is as,

$$C_D=B_T/(3*\omega) =194.169 \ \mu F.$$

(f) The kVA rating of the compensator is as,

$$Q_{eq}=3V_{LL}{}^2B_D=3*415^2*0.061= 31517.175 \ VA = 31.517 \ kVA.$$

Well, after the compensation the load line voltage is 415. And the compensator current are to be V L line voltage into the B D compensator you can call it susceptance and that is 415 into 0.661[FL] current 625.315. The value of capacitor for power factor correction and voltage regulation is C D equal to B D upon 3 omega, and it comes 194.169 micro Farad.

And kVA rating of the compensator is now 3 V L square into B D. And we by keeping 3 into 415 square into 0.661 that comes 31517.17 VA it comes the 31.517 kVA as the compensator kVA rating.[FL] This completes this problem.

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Q.8 A three-phase, three-wire, **unbalanced delta connected load** $\{Z_{ab}=(5.0+j2.0)$ pu, $Z_{bc}=(4.0+j1.2)$ pu and $Z_{ca}=(7+j2)$ pu$\}$ has an input line-line voltage of 415V, 50Hz, AC supply and base impedance of 5.25 ohms per phase. It is to be realized as a balanced unity power factor load on three-phase supply system using a shunt compensator consisting lossless passive elements (L or C). Calculate (a) supply line currents, (b) the value of compensator elements (in Farads or Henries), (c) compensator currents, (d) its kVA rating, and (e) equivalent per phase resistance (in ohms) of the compensated load.

[FL] Coming to another numerical examples number-8, a three-phase, three-wire, unbalanced delta connected load which have a let across the line ab Z ab equal to 5 plus 2 j 2.0 per unit and Z b 4.0 plus j 1.2 ohm per unit per unit and Z ca 7 point j 2 per unit has an input line voltage of 415, 50 Hertz ac supply and base impedance of 5.25 ohm per phase.

And it to be realized as a balance unity power factor load on three-phase supply system using a shunt compensator consisting lossless element. Calculate the a supply line current; b, the value of compensator element; c, compensator current; and d, its kVA rating; and e, equivalent per phase resistance of the compensator load because after compensation it should have as a unity power factor load on the balance load in supply system.

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Schematic diagram and performance waveforms
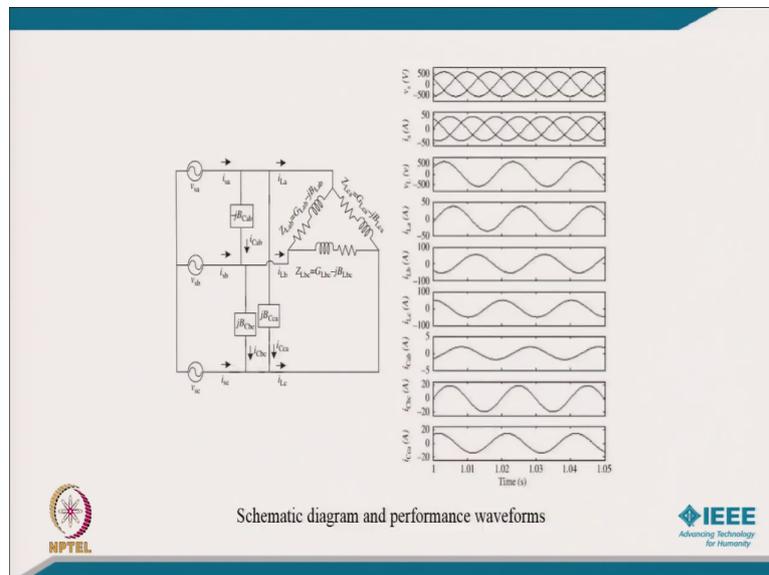
[FL] Coming to the solution I mean of this[FL] this is the typically the network you can just see that we have unbalanced load connected in delta, and then we have a compensator element for across all three you can call it delta connected load with the three elements such that compensator is also connected in delta across the each branch.

And compensator is responsible not I mean for power factor correction and balancing the load also across the supply. And these are of course, after getting the design on the waveform are plotted I mean and you can see those supply currents are in phase with the supply voltage. And typically all other waveform of compensator currents are also given here.

Solution: Given that, supply voltage, V_s = 415 V, frequency of the supply, f = 50 Hz, a three-phase, three-wire, unbalanced delta connected load of $\{Z_{ab}$ = (5.0+j2.0) pu, Z_{bc} = (4.0+j1.2) pu and Z_{ca}= (7+j2) pu$\}$ with base impedance of 5.25 ohms per phase.

Load impedances, Z_{lab} = (26.25+j10.5) Ω, Z_{Lbc} = (21+j6.3) Ω and Z_{Lca} = (36.75+j10.5) Ω. Load admittances, Y_{lab} = (0.0328-j0.0131) mhos, Y_{Lbc} = (0.0437-j0.0131) mhos and Y_{Lca} = (0.0252-j0.0072) mhos.

The total load conductance is as, G_{LT} = G_{Lab}+ G_{Lbc}+ G_{Lca}= 0.1017 mhos.

(a) Supply line currents after compensation, I_{sa}=(V_s*G_{LT}/$\sqrt{3}$) 0°A = I 0°A, I_{sb}= I ∠120°A, I_{sc} =I ∠ 240°A.

I_{sa} = (V_s*G_{LT}/$\sqrt{3}$) ∠ 0°A = 24.36 ∠ 0°A, I_{sb} = 24.36 ∠ 120°A, I_{sc}=24.36 ∠ 240°A.

(b) Compensator susceptances, B_{cab} = −B_{Lab} + (G_{Lca}-G_{Lbc})/$\sqrt{3}$,

B_{Cbc}=− B_{Lbc} + (G_{Lab}-G_{Lca})/$\sqrt{3}$,

B_{Cca} =− B_{Lca} + (G_{Lbc}-G_{Lab})/$\sqrt{3}$

[FL] Coming to the solution of this problem given that supply voltage V S equal to 415 and frequency of 50 Hertz a three-phase, three-wire unbalanced delta connected load of Z ab equal to 5.0 plus j 2 per unit, and Z b 4.0 plus j 1.2 per unit, and Z ca is 7point 7 plus j 2 per unit with a base impedance of four point 5.25 ohms per phase. We can find out the actual impedance of the all three by multiplying the per unit value with the base impedance.

[FL] Load impedance comes Z lab comes 26.25 plus j 10.5 ohm and Z L bc, it comes 21 plus j 6.4 ohm, and Z L ca 36.75 plus j 10.5 ohm. And load admittances come Y Lab equal to 0.0328 minus j 0.03 mho, and Z bc 0.0437 minus j 0.0131 mho and y this Y L ca 0.02252 minus j 0.072 mho.

[FL] Total load conductance here which is a sum of all three conductance as they come G L T equal to 0.1017 after putting the value of all three conductance of the load. And supply line

current after the compensation I mean from the relation it will come I sa equal to V S into G LT by root 3 into at a angle of 0. It comes at typically I times this.

And similarly your B phase will be 120 degree apart and I sc will be your 240 degree apart. And the magnitude of current I mean we can calculate I sa equal to V S into G LT by root 3 into at the angle of 0, it comes 24.36 at the angle 0, and I sb 24.36 ampere at the angle of 120 degree, I sc 26.36 which is equal to the all three balance current at the phase angle of 240 degree.

So, that cause the balance three-phase channel current at unity power factor in phase with the supply voltage. And we can find out the compensator susceptances that we say we will applying the relation which we derived in the previous lecture[FL] minus B Lab plus G Lac a minus G L cb divide by root 3. Similarly, for B cb minus B Lb in bracket G Lab minus G Lac divide by root 3, and B L ca equal to B L ca plus G L bc minus G Lab by root 3.

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Substituting values, $B_{Cab}= 0.0024$, $B_{Cbc}=0.0175$, $B_{Cca}=0.0134$ mhos.
Values of elements of compensator, $C_{Cab}= B_{Cab}/\omega=7.639$ µF, $C_{Cbc}= B_{cbc}/\omega=55.83$µF, $C_{Cca}= B_{Cca}/\omega=42.81$ µF.

(c) The compensator phase currents,
$I_{Cab}= V_s*B_{Cab}=1.0118$ A, $I_{Cbc}= V_s*B_{cbc}=7.2800$ A , $I_{Cca}= V_s*B_{Cca}=5.5817$ A .

(d) The compensator VA rating, $Q_C=V(|I_{Cab}|+|I_{Cbc}|+|I_{Cca}|)=5757.5$ VA=5.757 kVA.

(e) The equivalent delta connected resistance (in ohms) of the compensated load, $R_{eq}=3/G_{LT}= 29.50$ Ω.

And then of course, putting the value of all these, we get the compensator susceptances B Ca 0.0224 mho, B ca 0.0175 mho, and B Cca 0.0134 mho. And the value of elements come from there if we calculate the value of in first element in the capacitance[FL] it is a B Cca by omega that comes 7.639 micro Farad.

And across the B c it comes as a capacitance[FL] it is a B cb by omega[FL] 55.83 micro Farad; and for C Ca it also another capacitor as a B ca omega[FL] that is also typically comes from the previous value is come 42.81 micro Farad, [FL]that is a compensator value for all three.

And compensator phase current, we can find out V S into the this susceptances[FL] it comes 1.0118 ampere and I Cab second compensator I mean across the B c line come B sb ccb and it comes 7.28 ampere, and I ca for V S B ccb[FL] it comes 5.5817 ampere. And compensator

VA rating comes like voltage which is equal across and we can take a mod of all these three current.[FL] it comes typically 5.75 kVA.

And equivalent delta connected resistance in ohms of this, we can find out R equal to 3 divide by G LT, and it comes 29.50 ohm per phase like I mean.[FL] That provide the typically you can call it like not only power factor correction but the load balancing what we demonstrate in this example.

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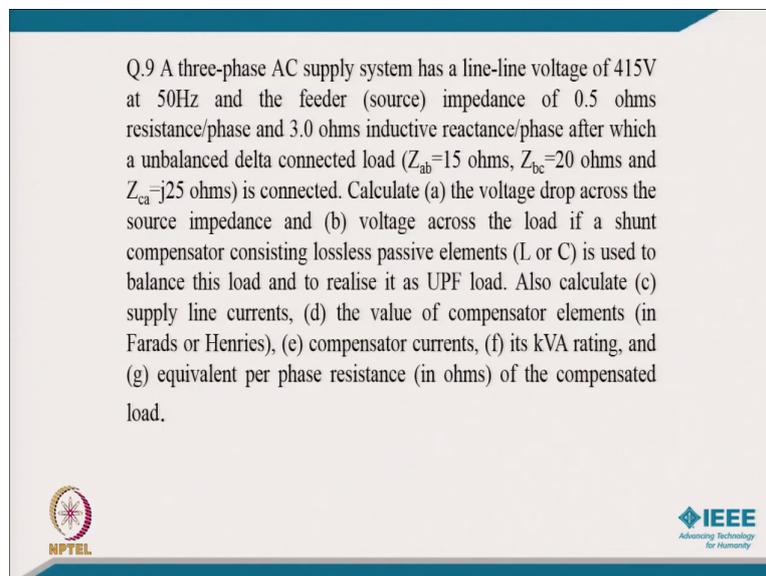
Q.9 A three-phase AC supply system has a line-line voltage of 415V at 50Hz and the feeder (source) impedance of 0.5 ohms resistance/phase and 3.0 ohms inductive reactance/phase after which a unbalanced delta connected load (Z_{ab}=15 ohms, Z_{bc}=20 ohms and Z_{ca}=j25 ohms) is connected. Calculate (a) the voltage drop across the source impedance and (b) voltage across the load if a shunt compensator consisting lossless passive elements (L or C) is used to balance this load and to realise it as UPF load. Also calculate (c) supply line currents, (d) the value of compensator elements (in Farads or Henries), (e) compensator currents, (f) its kVA rating, and (g) equivalent per phase resistance (in ohms) of the compensated load.

Coming to another example typically example number-9, a three-phase ac supply system has a line voltage of 415 volt at 50 Hertz, and the feeder impedance of 0.5 ohm resistance per phase and 3 ohm, ohms inductive reactance per phase after which a unbalanced delta connected load with Z ab equal to 15 ohm, Z bc of 20 ohm, and Z ca 25 ohms is connected.

[FL]Calculate the, a - voltage drop across the source impedance, the voltage across the b voltage across the load if shunt compensator consisting of lossless passive element is used to balance this load and to realize as a it as a unity power factor load. Moreover calculate the supply line current, the value of compensator element compensator current, and its kVA rating, and equivalent per phase resistance of the compensated load after the compensation.

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Schematic diagram and performance waveforms
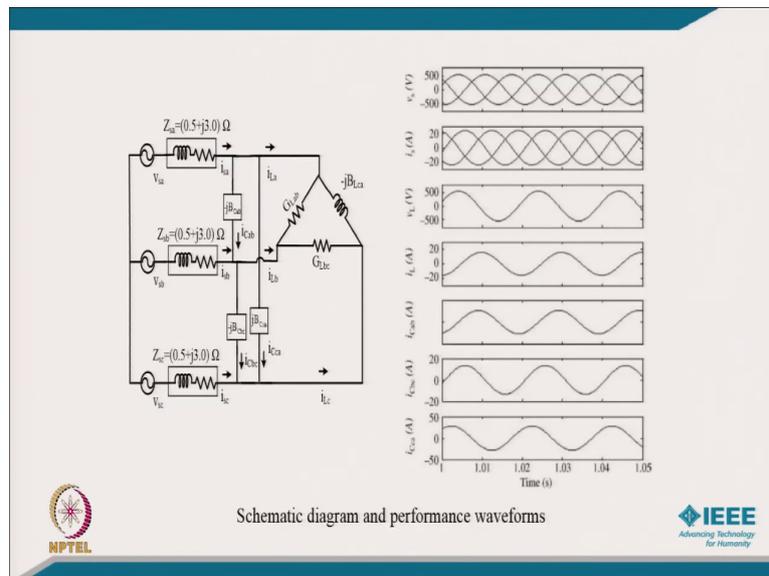
[FL]This is the typically the circuit configuration that we have a source impedance which is equal for all three-phases in series. And we have a unbalanced load which the value of two conductance and another is susceptance. And then we have a compensator element for across the all these delta connected load.[FL] After proper design and getting the value this waveform are plotted. And you can clearly see that I mean the power factor is corrected to typically to unity like I mean after the compensation.

Solution: Given that, supply voltage, V_s = 415 V, frequency of the supply, f = 50 Hz, a three-phase, three-wire, unbalanced delta connected load of (Z_{Lab}= 15 ohms, Z_{Lbc}= 20 ohms and Z_{Lca}= j25 ohms) with the feeder (source) impedance of 0.5 ohms resistance/phase and 3.0 ohms inductive reactance/phase. Z_s= 0.5+j3.0

Load admittances, Y_{Lab}= 0.0667 mhos, Y_{Lbc}= 0.0500 mhos and Y_{Lca}= -j 0.0400 mhos.

Equivalent star connected conductance and resistance after compensation, $G_{LT} = G_{Lab} + G_{Lbc} + G_{Lca}$ = 0.1167 mhos, R_{LT} = 8.57 Ω.

Total impedance/phase in star connection, $Z_{TY} = Z_S + R_{LT}$ = (9.0714+j3) Ω= 9.55 ∠ 18.30°Ω.

The source current after compensation is $I_s = V_s/(\sqrt{3}*|Z_{TY}|)$ = 25.06 ∠-18.30°.

(a) The voltage drop across the source impedance, $V_{ZS} = I_s * Z_s$ = 76.26 V.

(b) The voltage across the load, $V_{ZL} = I_s * R_{LT}$ = 214.909V/phase = 372.29 V/line

Coming to the solution I mean given that supply voltage of 415 volt frequency of 50 Hertz and three-phase, three-wire unbalanced delta connected load of your Z Lab across the line ab is 15 ohm, and Z bc 20 ohms and Z L ca your j 25 ohm with a feeder impedance of 0.5 ohms resistance per phase and 3 ohm inductive reactance per phase that comes equal to 0.0 plus j 3 ohm. And load admittance we calculate 1 upon Z it comes L ab is 0.0667 mho, and Y Lb 0.0500 mho, and Y L ca minus j 0.04 mho.

The equivalent star connected conductance and resistance after compensation I mean we have to add all conductance as a relation we derived G LT equal to G lab plus G L bc G lc,[FL] it comes 0.1167, and R LT comes as 8.57 ohm. And the total impedance in the star connected equivalent load I mean, like in balanced load is along with the source impedance. And this

resistance comes like point 0 9 0.074 plus j 3 and it can be converted into the polar typically polar coordinate 9.55 at the angle 18.30 degree ohms.

And the source current after the compensation which equal to I s equal to V s upon root 3 to get the phase voltage into Z TY in star connection [FL] that comes around 25.06 at the minus at the angle 18.30 degree ampere. And voltage drop across the source impedance will be I s Z s [FL] that comes your 76.26 volt.

And voltage across the load comes V I s into R LT that is 214 9.09 ohm that is the line voltage comes seven, 372.29 in place of four typically 415[FL] because of the source impedance the voltage across the load reduces like even you put this load as you balance load.[FL] These three load across the this typically line like.

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(b) Supply line currents after compensation,
$I_{sa} = (V_s/(\sqrt{3}*Z_{TY})) \angle -18.30°A = I \angle -18.30°A$, $I_{sb} = I \angle -138.30°A$, $I_{sc} = I \angle 101.70°A$.
$I_{sa} = 25.06 \angle - 18.30°A$, $I_{sb} = 25.06 \angle -138.30°A$,
$I_{sc} = 25.06 \angle 101.70 °A$.
(d) Compensator susceptances, $B_{Cab} = -B_{Lab} + (G_{Lca}-G_{Lbc})/\sqrt{3}$,
$B_{Cbc} = - B_{Lbc} + (G_{Lab}-G_{Lca})/\sqrt{3}$, $B_{Cca} = -B_{Lca} + (G_{Lbc}-G_{Lab})/\sqrt{3}$
Substituting the values, $B_{Cbc} = 0.0385$ mhos, $B_{Cab} = -0.0289$ mhos,
$B_{Cca} = 0.0304$ mhos.
Values of elements of compensator, $C_{Cbc} = B_{Cbc}/\omega = 122.55$ µF, $C_{Cab} = 1/(B_{Cab} \omega) = 110.14$ mH, $C_{Cca} = B_{Cca}/\omega = 96.695$ µF.
(e) The compensator phase currents,
$I_{Cab} = V_s*B_{Cab} = 11.98$ A, $I_{Cbc} = V_s*B_{Cbc} = 15.97$ A ,
$I_{Cca} = V_s*B_{Cca} = 12.60$ A .
(f) The compensator VA rating, $Q_C = V(|I_{Cab}|+|I_{Cbc}|+|I_{Cca}|) = 16832$ VAR = 16.832kVAR.
(g) The equivalent delta connected resistance (in ohms) of the compensated load, $R_{eq} = 3/G_{LT} = 25.71$ Ω.

Now, coming to b part, the supply current after the compensation I sa equal to V s upon root root 3 Z ly at the angle of minus 18.23. Similarly, for all three current balance[FL] I sa will be 25.6 at the angle of minus 18.30 degree ampere. And similarly for b phase 25.06 ampere at the angle of minus 13 138.30 degree, and I sc will be 25.06 ampere at the angle of 101.70 ampere.

And the compensator susceptances will be from these relation minus B Lab plus G L a minus G L bc by root 3, [FL]this relation we have derived[FL] putting the value[FL]it comes the compensator value B Cbc equal to 0.0385 mho, and B Cab will be minus 0.0289, and B Cca is 0.034 mho.

And value of compensator element will be capacitance for a line across ab will be your B Cca by omega,[FL] it comes 122, 122.55 micro Farad. Similarly, for your C ab is equal to typically as a, your inductance that is 110.14 milli Henry. And similarly capacitor across the line ca will be your 96.69 typically 5 micro Farad.

And the compensator phase current will be of course we can find out V s into cb that comes 11.98 ampere, for the bc it comes like 15.97 ampere, and for ca it comes again 12.60 ampere. And compensator VA rating we can find out V into absolute value of all the current it comes 16.832 kVAR because it is all reactive elements there.

And the equivalent delta connected load of compensator load will be R equivalent 3 by G LT into that is comes about 25.71 of equivalent star connected load like so that is completes the 9th problem.

Q.10 A three-phase AC supply has a line-line voltage of 415V at 50Hz and feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase after which a unbalanced delta connected load having Z_{ab}=15 ohms, Z_{bc}=20 ohms and Z_{ca}=25 ohms is connected. Calculate (a) the voltage drop across the source impedance and (b) the voltage across the load if a shunt compensator consisting lossless passive elements (L or C) is used to balance these loads and to raise the voltage to same as input voltage (415V). Also calculate (c) supply line currents, (d) the value of compensator elements (in Farads or Henries), (e) compensator currents, (f) its kVA rating, and (g) equivalent per phase resistance (in ohms) of the compensated load.

Now, we come to the solution typically another example of 10th numerical example, a three-phase ac supply system where line voltage of 415 and 50 Hertz and feeder impedance of 0.5 ohms and 2.5 ohms inductive reactance after which unbalanced delta connected load Z ab 15 ohm, Z bc 20 ohm and Z ca of 25 ohms is connected.

Calculate a voltage drop across the source impedance, the voltage across the load if shunt compensator consisting lossless passive element is used to supply the loads and to raise the voltage at the same as the 415 volt. And also calculate the supply line current, the value of compensator element, compensator currents, and its kVA rating, equivalent per phase resistance of the compensator load after this 0 voltage regulation like in that case.

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Schematic diagram and performance waveforms
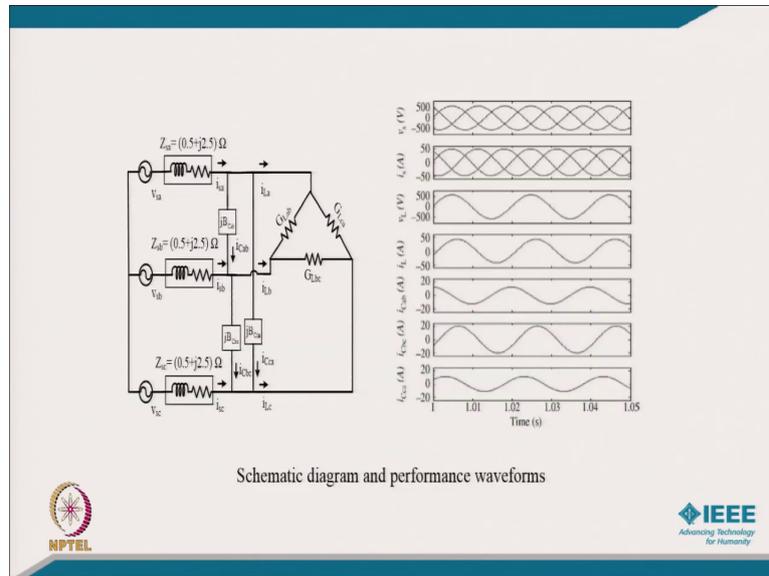
[FL] Well, this is the typically again network. We have a balanced source impedance, I mean which is responsible to reduce the voltage, but we have to regulate the 0 for the 0 voltage regulation. And we have a typically this unbalanced load. And putting the compensator element, we should be able to balance the load.

And then we should be able to regulate the voltage[FL] we have to find out the I mean the compensator elements value in susceptances, which is lossless element I mean in terms of these elements like.

Solution: Given that, supply voltage, $V_s = 415$ V, frequency of the supply, $f=50$ Hz, a three-phase, three-wire, unbalanced delta connected load of ($Z_{Lab}=15$ ohms, $Z_{Lbc}=20$ ohm and $Z_{Lca}=25$ ohms) with feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase.

Load admittances, $Y_{Lab}=0.0667$mhos, $Y_{Lbc}=0.05$mhos and $Y_{Lca}= 0.04$ mhos.

Compensator susceptances for the load balancing and power factor correction,

$B_{CabL}= - B_{Lab}+(G_{Lca}-G_{Lbc})/\sqrt{3}$, $B_{CbcL}= - B_{Lbc}+(G_{Lab}-G_{Lca})/\sqrt{3}$, $B_{CcaL}= - B_{Lca}+(G_{Lbc}-G_{Lab})/\sqrt{3}$

Substituting the values, $B_{Cab1}= - 0.0058$mhos, $B_{Cbc1} = 0.0154$mhos, $B_{Cca1}= - 0.0096$mhos.

Star equivalent conductance after load balancing/power factor correction, $G_{LT}= G_{ab}+G_{bc}+G_{ca}= 0.1567$ mhos.

The star equivalent resistance after load balancing and power factor correction, $R_{LT}=1/G_{LT}= 6.3830$ Ω.

[FL] Given that supply voltage of 415 volt frequency of 50 Hertz and a three-phase, three-wire unbalanced delta connected load with the impedance of across I mean line of ab is 15 ohm, line bc is 20 ohm, and line ca is 25 ohm with the feeder source impedance of 0.5 ohms resistance and 2.5 ohm inductive reactance per phase. And load admittances will be corresponding to the reciprocal of this Y Lab will be 1 upon Z lab equal to will comes around 0.0067 mho, and similarly Y Lb comes 0.05 ohm mho, and Y Lca comes 0.04 mho.

[FL] This compensator susceptance of load balancing and power factor correction comes that we derive the relation for three-wire system in terms of these load susceptance and conductance. And after putting value, it comes like bl cab 1 0.058, and blcb 1 0.05 mho and we say zero point so we can call it according to star equivalent conductance after the load

balancing and power factor correction it comes G LT some of the all three load conductance it comes 0.1567 mho.

And the star connected equivalent resistance after load balancing and power factor correction R LT equal to 1 upon G LT that is come 6.383 ohm like.

(Refer Slide Time: 22:49)

Let the substance of value B_{cv} mhos is to be connected in parallel to the star equivalent load $G_{LY}=G_{LT}$ (as per phase representation) to raise the load voltage equal to the input voltage ($V_L=V_S$). The basic equation to regulate the load voltage equal to input voltage is as,
$$|V_L|=|V_S/[\{(R_s+jX_s)+1/(G_{LY}+jB_V)\}]|*|1/(G_{LY}+jB_V)|=|V_S|$$
Solving this equation, the value of B_{cv} is as,
$$B_{cv}=[X_S\pm\{\sqrt{X_S^2-(X_S^2+R_S^2)(2R_SG_{LY}+R_S^2G_{Ly}^2+X_S^2G_{Ly}^2)}\}]/(X_S^2+R_S^2)$$
Substituting the values of X_S=2.5 Ω, R_S=0.5 Ω and G_{LY}=0.1567 mhos and considering "-" sign in "±", for lower value of the compensator, the value of B_{cv} isas, B_{cv}=0.0695 mhos.
$$jX_{cv}= 1/jB_{cv}= -j14.38\ \Omega$$
$$Z_{LT} = R_{LT}*(-jX_{cv})/(R_{LT} - jX_{cv}) = 5.3328 - j2.3666 = 5.834\angle-23.94°\ \Omega$$
Supply line currents after compensation,
$$I_s = V_{sa}/(Z_{LT}\sqrt{3})\angle\ 0°A = 239.6\angle\ 0°/(5.834\angle- 23.94°) = 41.06 \angle 23.94°A$$

Let the susceptance value of B cv mho to be connected in parallel to the star equivalent load that is G LY equal to G LT as per the phase representation to raise the load voltage equal to the your input voltage. The basic equation to regulate the load voltage to equal to the input voltage is that load voltage magnitudes will be (Refer Time: 23:02) voltage.

And we can find out the load voltage in terms of source impedance, and the load admittance along with the compensator element which is shown this in equation. And the derivation

solving this equation which we derive many times the value of B cv become X S plus minus under root X S square plus X S square plus R equivalent to 2 R S G LY plus R S square G LY square plus X S square G LY square and divide by X S square R S square.

[FL] Substituting the value of X S is equal to 2.5, R S equal 0.5, and G LY 0.01567. And considering the minus sign in plus minus for lower value of compensator the value of B cv is as B cv equal to 0.60695 mho. And that will be j X cv equal to 1 upon j B that comes minus j a 14.38 ohm. And Z LC, I mean along with R LT and that is this admittance comes around 5.3328 ohm minus 2.3666 ohm. And which comes 5834 at the angle of 23.935 ohm.

And supply line current after the compensation will be I s equal to because now load voltage is same as the source voltage[FL] it comes V sa upon Z LT into root 3 at the angle of 0, it comes 239 after putting the value of this both element[FL] it comes 41.06 at the angle of 23.935. I mean the it means the typically the load have to be made this current have to be made leading only then you will get the 0 voltage regulation like that is meaning of that like.

(Refer Slide Time: 24:40)

(a) The voltage drop across the source impedance, $V_{ZS}=I_s*Z_s=104.70$ V.
(b) The voltage across the load, $V_{ZL}=I_s*Z_{LT}=239.6$ V/phase.
(c) Supply line currents after compensation,
$I_{sa}=V_s/(Z_{LT}\sqrt{3})\angle 23.94°A = 41.06\angle 23.94$ °A, $I_{sb}= 41.06\angle-96.06°$A,
$I_{sc}= 41.06 \angle-216.06°$ A.
Susceptance for the voltage regulation is as, $\mathbf{B_{V\Delta} = B_{cv}/3}$=0.0232 mhos.
Total susceptances for the load balancing and voltage regulation are as follows,
$B_{Cab}=B_{V\Delta}+B_{CabL}$=0.0174 mhos, $B_{Cbc}=B_{V\Delta}+B_{CbcL}$= 0.0386 mhos, $B_{Cca}=B_{V\Delta}+B_{CcaL}$=0.0136 mhos.
Values of elements of compensator, $C_{Cab}= B_{Cab}/\omega$=55.391 μF, $C_{Cbc}=B_{Cab}/\omega$=122.78 μF, $C_{Cca}= B_{Cca}/\omega$=43.13 μF.
(e) The compensator phase currents,
$I_{Cab}= V_s*B_{Cab}$=7.2216 A, $I_{Cbc}= V_s*B_{Cbc}$=16.00 A , $I_{Cca}= V_s*B_{Cca}$= 5.62 A
(f) The compensator VA rating, $Q_C=V(|I_{Cab}|+|I_{Cbc}|+|I_{Cca}|)$=11974 VA=11.974 kVA.
(g) The equivalent delta connected resistance (in ohms) of the compensated load, $R_{eq}=3/G_{LT}$=19.14 Ω.

[FL]We can now calculate the voltage drop across the source impedance is I s Z s,[FL] it comes one putting the value of I s and Z S, we get this 104.7. And voltage across the load comes like now I s into Z LT that comes same as the supply voltage I mean 415 by root 3 that is nothing but 239.6 phase after the voltage regulation.

And supply line currents after compensation come I sa V L upon Z LT in root 3[FL] it at the angle of 23.93 it comes 41.06 at the angle of 23.93. And other two phases will be at just exactly 120 degree apart with the same magnitude.

[FL] Susceptance for voltage regulation will be as B V delta equal to B cv by 3, and it will be 0.23 mho. And total susceptance for load balancing and voltage regulation we can calculate some of the, this and which are used earlier for load balancing. And we come get the three

value typically 0.0174 across line b, and across line bc it comes 0.036 mho; and across line cl, it comes 0.0136 mho.

Value of element compensator elements comes Cab equal to B cab omega that is come fifty five point 55.391 micro Farad. And for across your line ab, it comes 122.78 ohm; and line ca is comes around 43.13 micro Farad. And compensator phase current will be this line voltage multiplied this compensator element, it comes 7.2216; and then for line bc, it comes 16 ampere; and line ca it comes 5.62 ohm.

And compensator VA rating is absolute sum of all these three current multiplied the voltage[FL] it comes like your 11.974 kVA. And equivalent delta connected resistive load of the compensator that is R eq is 3 upon G LT it comes 19.14 ohm.

(Refer Slide Time: 26:32)

Q.11 A three-phase, three-wire, unbalanced isolated neutral star connected load (Z_a=5.0+j2.0 pu, Z_b=4.0+j1.2 pu and Z_c=6+j2 pu) has an input line-line voltage of 415V, 50Hz, AC supply and base impedance of 5.30 ohms per phase. It is to be realized as balanced unity power factor load on the three-phase supply system using a shunt compensator consisting lossless passive elements (L or C). Calculate (a) supply line currents, (b) compensator currents, (c) the value of compensator elements (in Farads or Henries), (d) its kVA rating, and (e) equivalent per phase resistance (in ohms) of the compensated load.

Well, coming to the another example, I mean example number-11, a three-phase, three-wire unbalance isolated neutrally star connect neutral isolated neutrally star connected load with a Z a equal to 5.0 plus j 2 per unit, and Z b 4.0 plus j 1.2 per unit, and Z c 6 plus j 2 per unit has an input line voltage of 415 volt, 50 Hertz, AC supply and base impedance of 5.3 ohms per phase.

And it to be realized as a balance unity power factor load on the three-phase supply system using a shunt compensator consisting a lossless element.[FL] Calculate the supply line current, compensator current, value of compensator element, its kVA rating, and e equivalent per phase resistance of the compensated load.

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Schematic diagram and performance waveforms
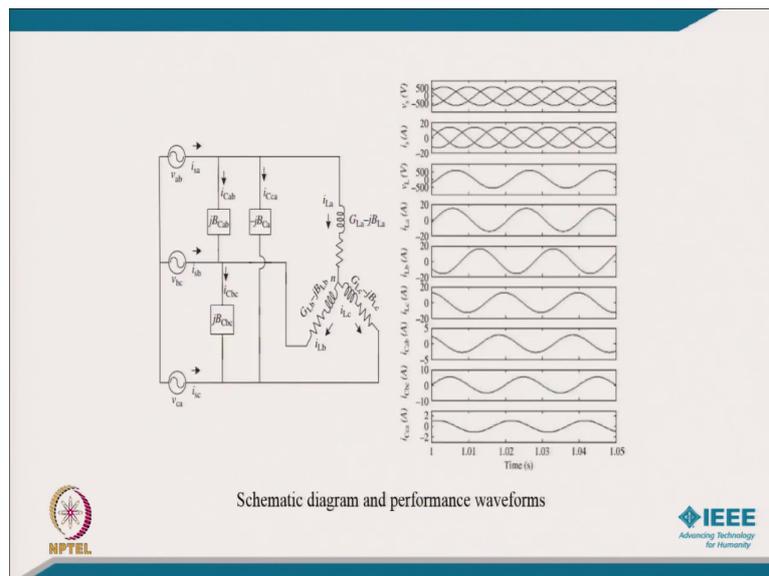
So, these are typically the network that we have unbalanced isolated star connected load with the compensator which is responsible for maintaining the unity power factor and balance

current in the supply system. And after designing, getting the value, these waveform are plotted which give you the typically the unity power factor current in phase with the, your supply volt current like supply voltage.

(Refer Slide Time: 27:40)

Solution: Given that, supply voltage, V_s = 415 V, frequency of the supply, f=50 Hz, a three-phase, three-wire, unbalanced delta connected load of $\{Z_{La}=(5.0+j2.0)$ pu, $Z_{Lb}=(4.0+j1.2)$ pu and $Z_{Lc}=(6+j2)$ pu\} with base impedance of 5.3 ohms per phase.
Load impedances in star connection, $Z_a=(26.5+j10.6)$ Ω, $Z_b=(21.2+j6.36)$ Ω and $Z_c=(31.8+j10.6)$ Ω.
Load admittances in star connection, $Y_a = (0.0325 - j0.0130) = 0.035$ $\angle-21.80°$ mhos, $Y_b = (0.0433 - j0.0130) = 0.0452 \angle-16.7°$ mhos and $Y_c = (0.0283 - j0.0094) = 0.0298 \angle-18.43°$ mhos.
Load admittances in equivalent delta connection,
$Y_{ab}=(Y_aY_b)/(Y_a+Y_b+Y_c)$, $Y_{bc}=(Y_bY_c)/(Y_a+Y_b+Y_c)$, $Y_{ca}=(Y_cY_a)/(Y_a+Y_b+Y_c)$.
$Y_{ab}=(0.0136-j0.0049)$ mhos,
$Y_{bc}=(0.0118-j0.0034)$ mhos and
$Y_{ca}=(0.0088-j0.0035)$ mhos.
$G_{LT}=G_{ab}+G_{bc}+G_{ca}=0.0342$ mhos

[FL] Coming to the solution given that the supply voltage V s equal to 415 volt, and frequency of 50 Hertz, a three-phase, three-wire unbalanced delta connected load with a value of Z La equal to 5.0 plus j 2 per unit, and Z Lb 4 per unit plus j 1.2 per unit, and Z Lc 6 plus j u per unit with a base impedance of 5.3 ohm per phase.

And getting a load impedance in star connection with a value of per unit multiplying[FL] it comes Z a equal to 26.5 plus j 10.6, and Z b is 21.2 ohm plus j 6.36 ohm, and Z c 31.8 plus j 10.6 ohm load admittance will be just reciprocal of them[FL] that will be like typically 0.035 mho at the angle of minus 21.80 degree.

Similarly, for your b phase, it will be your 0.04 point two at the mho at the angle of minus 16.67, and your c phase will be your 0.0298 at the angle of minus 18.43 mho. And we can find out load admittance in equivalent delta connection by converging delta to star connection by these formula.

Star to delta conversion, and we get the three these 3 mhos were actually for the line admittances. And from this we can find out the conductance of all three line from these three first element and that comes to equivalent to 0.0 typically of your 342 mho, which comes after the typically of load balancing.

(Refer Slide Time: 29:13)

(a) Supply line currents after compensation, $I_{sa}=(V_s G_{LT}/\sqrt{3}) \angle 0°A = I\angle 0°A$, $I_{sb}= I \angle 120°A$, $I_{sc} =I \angle 240°A$.
$I_{sa}=(V_s G_{LT}/\sqrt{3})\angle 0°A = 8.1847\angle 0°A$, $I_{sb}= 8.1847\angle 120°A$, $I_{sc}= 8.1847\angle 240°A$.
(b) Compensator susceptances, $B_{Cab}=-B_{ab}+(G_{ca}-G_{bc})/\sqrt{3}$, $B_{Cbc}=-B_{bc}+(G_{ab}-G_{ca})/\sqrt{3}$, $B_{Cca}=-B_{ca}+(G_{bc}-G_{ab})/\sqrt{3}$
Substituting the values, $B_{Cab}=0.0032$, $B_{Cbc}=0.0062$, **$B_{Cca}=0.0024$ mhos.**
Values of elements of compensator, $C_{Cab}= B_{Cab}/\omega=10.09$ μF, $C_{Cbc}= B_{Cbc}/\omega=19.622$ μF, **$C_{Cca}= B_{Cca}/\omega=7.77$ μF.**
(c) The compensator phase currents,
$I_{Cab}= V_s * B_{Cab}=1.3161$ A, $I_{Cbc}= V_s * B_{Cbc}=2.5582$ A, $I_{Cca}= V_s * B_{Cca}=1.0131$ A.
(d) The compensator VA rating, $Q_C=V(|I_{Cab}|+|I_{Cbc}|+|I_{Cca}|)=2028.3$ VAR=2.02 kVAR.
(e) The equivalent delta connected resistance (in ohms) of the compensated load, $R_{eq}=3/G_{LT}= 87.82$ Ω.

And we can find out line current after compensation that is I sa V sa into G LT by root 3, and all three will be balanced.[FL] We can put the value of this V s G LT 1 by root 3, it comes 81; 8.1847 at the angle of 0. Similarly, for b phase at the angle of 120, again I the angle of your

240 degree. And come compensator susceptances from this relation, we can find out typically in the mho putting the value of this, and it comes typically you can call it the capacitance say I mean if you calculate 10.4, ab, across the ab[FL] it comes 10.09 micro Farad, and bc it comes 19.2622 micro Farad, and your line ca it comes 7.77 micro Farad.

And total compensator phase current I mean V s into this you can call it the your susceptances,[FL] it comes 1.3161 ampere. And for line bc, it comes 2.5582 ampere. Line ca, it comes 1.0131 ampere. The compensator VA rating comes as absolute value of these current multiply voltage,[FL] it come to 2028.3; and VA VAR rating that is 2.02 kVAR. An equivalent delta connected load comes RE equal to 3 upon G LT and that comes 87.82 ohms like on.

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Q.12 A three-phase, four-wire, 415V (line-line), 50 Hz ac supply system has a single-phase 7.5 kW unity power factor load connected across line and neutral. If it is required to eliminate neutral current using a shunt compensator consisting lossless passive elements (L or C), calculate (a) supply line currents, (b) the value of compensator elements (in Farads or Henries), (b) compensator currents, and (d) its kVA rating.

Well, coming to typically the example number example-12, this is on four-wire system in three-phase four-wire system for 15 volt, 50 Hertz ac supply system has a single-phase load 7.5 kilo Watt load unity power factor load connector across line to neutral. And it is required to eliminate the neutral current using a shunt compensator consisting of lossless passive element. And calculate the supply line current, the value of compensator element, and compensator current, and its kVA rating.

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Schematic diagram and performance waveforms
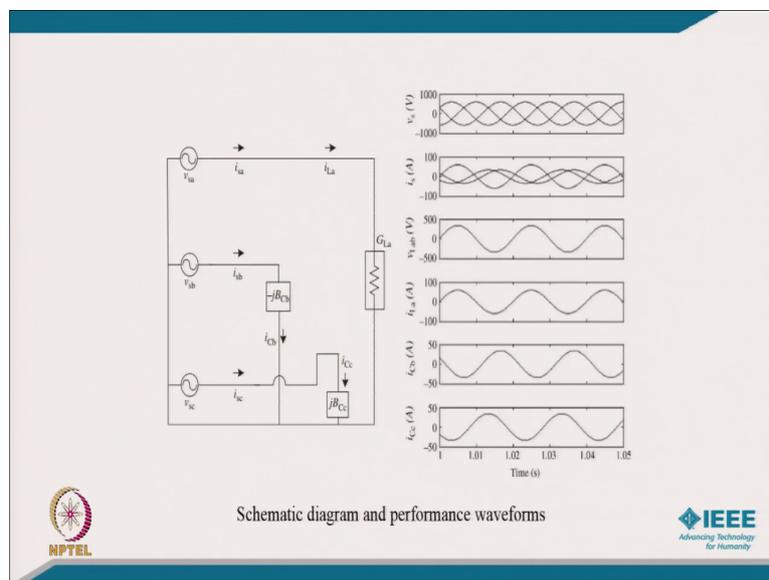
[FL]Here you can see the network here, I mean the load is connected between a and neutral. And by putting the compensator elements across the two line, we can eliminate the, this neutral current. This can be made 0. And after getting the value, it is shown here, and typically the neutral current is eliminated completely here in this case.

(Refer Slide Time: 31:19)

Solution: Given that, the supply phase voltage, $V_{sp}=415/\sqrt{3}$ V=239.6 V, frequency of the supply, f=50 Hz, a single-phase 7.5kW unity power factor load connected across line and neutral terminal.

The load impedance/phase is as, $Z_L = V_{sp}^2/P = 239.6^2/7500 = 7.65\ \Omega$.

The load admittance/phase is as, Y_L =0.13mhos.

It requires two susceptances across other two phases and neutral terminal to eliminate the neutral current and a susceptance across the loaded to correct the power factor to unity of single-phase load. However, the load is a unity power factor load hence only two susceptances for neutral current compensation are required.

(a) Supply line currents after compensation,

$I_{sa}=(V_{sp}G_{La})\ \angle 0°A$, $I_{sb}=(V_{sp}G_{La}/\sqrt{3})\ \angle 150°A$,

$I_{sc} =(V_{sp}G_{La}/\sqrt{3})\ \angle 210°A$.

$I_{sa}=(V_{sp}G_{La}/3)\ \angle 0°A =31.30\angle 0°A$,

$I_{sb} =(V_{sp}G_{La}/\sqrt{3})\ \angle 150°A =18.07\angle 150°A$,

$I_{sc} =(V_{sp}G_{La}/\sqrt{3})\ \angle 210°A = 18.07\angle 210°A$.

So, this is the only case of only eliminating the neutral current. You may have a reasonable solution.[FL] Here we have come with a unique solution given that supply voltage 415 by root 3, because it is a star connected load[FL] we have to find out per phase or you can call it the phase voltage[FL] that comes 239.6 volt, we can see 50 Hertz and single-phase load of 7.5 kilo Watt unity power factor load connector across the line to neutral.

[FL] We can find out the load impedance V s square by P. And putting the value, we can get this ohmic value 7.65 ohm. And the load admittance per phase comes of reciprocal of 0.13 mhos. It requires two susceptances across the other two phases and neutral terminal to eliminate the neutral current and susceptance across the loaded to correct the power factor to unity of single-phase load.[FL] However, the load is a unity power factor load hence the only two susceptance for neutral current compensation are required.

[FL] The supply line current after the compensation that is for a phase V sp G L upon at the angle; and I sb at the V s GL upon root 3 at the 15; and I sc V s G L upon root 3[FL] putting the value of this, we get typically the current in a phase 31.30 that is the typically the load current. And this is for b phase 18.067 at angle of 150 degree, and c phase 18.067 at typically at 210 degree because those are.

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(b) Compensator susceptances, $B_{Ca}=-B_{La}+(G_{Lb}-G_{Lc})/\sqrt{3}$, $B_{Cb}=-B_{Lb}+(G_{Lc}-G_{La})/\sqrt{3}$, $B_{Cc}=-B_{Lc}+(G_{La}-G_{Lb})/\sqrt{3}$ Substituting the values, $B_{Ca}=0.0$ mhos, $B_{Cb}=-0.0754$ mhos, $B_{Cc}=0.0754$ mhos.
Values of elements of compensator, $L_{Cb}=1/(B_{Cb}\omega)=42.2$ mH, $C_{Cc}=B_{Cc}/\omega=240.09$ µF.
(c) The compensator phase currents,
$I_{Ca}=V_{sp}*B_{Ca}=0.0$A, $I_{Cb}=V_{sp}*B_{Cb}=18.07 \angle 150°$ A, $I_{Cc}=V_{sp}*B_{Cc}=18.07 \angle 210°$A.
(d) The compensator VA rating, $Q_C=V(|I_{Ca}|+|I_{Cb}|+|I_{Cc}|)=8660$ VA=8.66 kVA.

And compensator susceptances we can find out from this relation which we derived already earlier. And we can find out B Ca is 0 because we do not need it is already resistive load. And B Cb typically minus 0.7454 mho, and B ca is 0.0 plus 0.075 mho. And value of elements will be across you have to put across the typically across the B to neutral it is a, inductance [FL]that comes 4.22 milli Henry.

And across the capacitance across the line c to ground is 240.09 and that cause the neutral current to go to 0, I mean like neutral current flows other two phases. The compensator of course, we can find out the element here in a phase 0; b phase we get the value for corresponding to this per phase voltage multiplied this susceptance, and c phase we are getting this.

And compensator element, we can take absolute value multiplied this voltage it comes 8.66 kVA.[FL] This example give you idea that neutral current can be compensated with lossless passive element even for single-phase pure resistive load like.
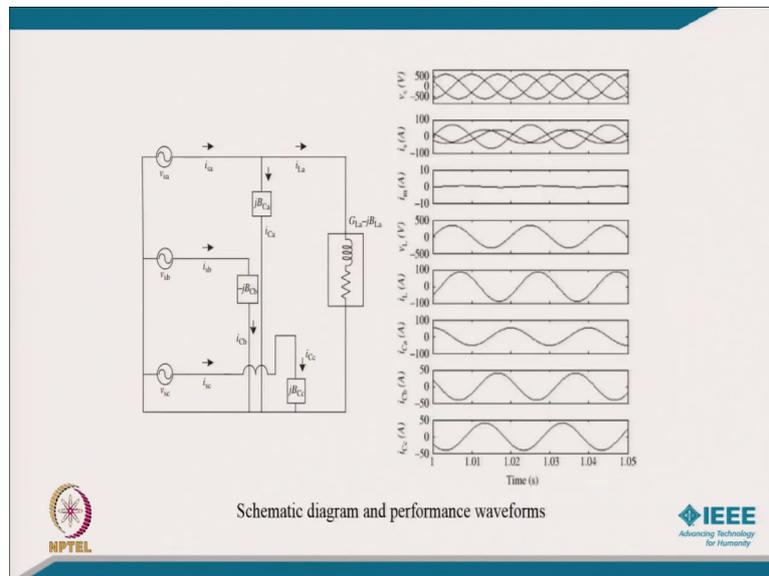
(Refer Slide Time: 33:44)
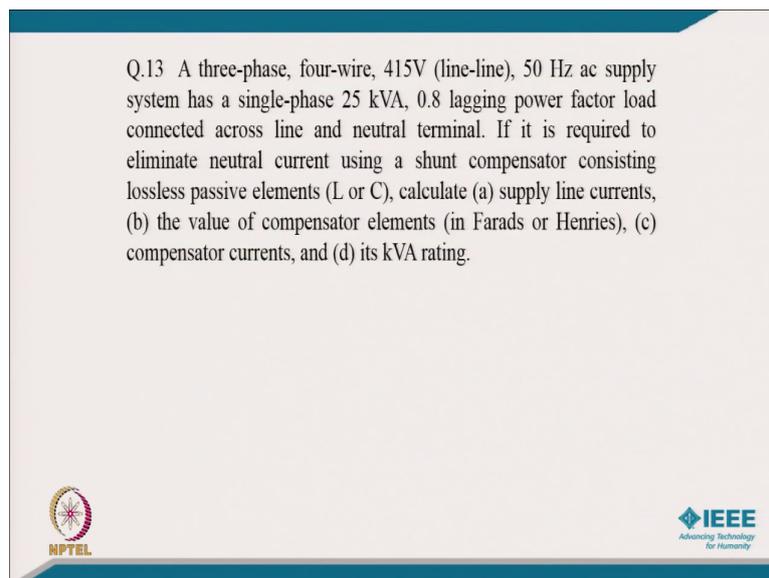
Q.13 A three-phase, four-wire, 415V (line-line), 50 Hz ac supply system has a single-phase 25 kVA, 0.8 lagging power factor load connected across line and neutral terminal. If it is required to eliminate neutral current using a shunt compensator consisting lossless passive elements (L or C), calculate (a) supply line currents, (b) the value of compensator elements (in Farads or Henries), (c) compensator currents, and (d) its kVA rating.

Coming to another example of 13 a three-phase four-wire 415 volt, 50 Hertz ac supply system has a single-phase 25 kVA, 0.8 lagging power factor load connected across line to neutral terminal. And if it is required to eliminate neutral current using a shunt compensator

consisting of lossless passive element. Calculate a supply line current, b the value of compensator element, and c compensator current, and d its kVA rating.

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Schematic diagram and performance waveforms

[FL] This is typical here the example I mean with neutral with load is connected between a phase and neutral that is a inductive load. And then of course, with this compensator value, we have to make unity. And after that we have to use two other compensator to make this neutral current 0, [FL] that is required to realize it as a unity power factor load on the supply and making neutral current as 0.

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Solution: Given that, the supply phase voltage, V_{sp}=415/√3 V=239.6 V, frequency of the supply, f=50 Hz, a single-phase 25 kVA, 0.8 lagging power factor load connected across line and neutral terminal. The load impedance/phase, Z_{La} =1.9166+j1.2534 = 2.29 ∠36.87° Ω. The load admittance/phase, Y_{La}= 0.3484−j0.2613 = 0.435∠-36.87° mhos.

It requires two susceptances across other two phases and neutral terminal to eliminate neutral current and a susceptance across the loaded to correct the power factor to unity of single-phase load.

a) Supply line currents after compensation,
I_{sa}=($V_{sp}G_{La}$) ∠0°A, I_{sb}=($V_{sp}G_{La}$/√3) ∠150°A,
I_{sc}=($V_{sp}G_{La}$/√3) ∠210°A.
I_{sa}=($V_{s}G_{La}$/√3) ∠0°A =83.4766∠0°A, I_{sb}=48.1953∠150°A,
I_{sc}= 48.1953∠210°A.
(b) Compensator susceptances, B_{Ca}= -B_{La}+(G_{Lb}-G_{Lc})/√3,
B_{Cb}= -B_{Lb} +(G_{Lc}-G_{La})/√3, B_{Cc}=-B_{Lc}+(G_{La}-G_{Lb})/√3
Substituting the values,

[FL] Coming to the solution part given that supply voltage is your 415 by root 3 that 239.6, we can say supply 50 Hertz and a single-phase load of 25 kVA, 0.8 lagging power factor load connected across line to neutral. And the loading your impedance is your one 1.9166 plus j 1234 that comes 2.29 ohm at the angle of 36.87 degree. And the load admittance will be reciprocal of this,[FL] it comes 0.435 at the angle of 30 minus 36.87 mho.

It requires two susceptance the other two phases and the neutral to eliminate the neutral current and susceptance across the load phase to make unity power factor of single-phase load.[FL]This comes like a typically the all the three-phase current like of the supply.

And it comes after putting the value it comes 80 typically 86.477 ampere at the angle of 0. And similarly for b phase, 48.1953 at the angle of 150 degree; and I sc at the 48.19 typically at the angle of 240 like. And compensator susceptance is will be from this relation.
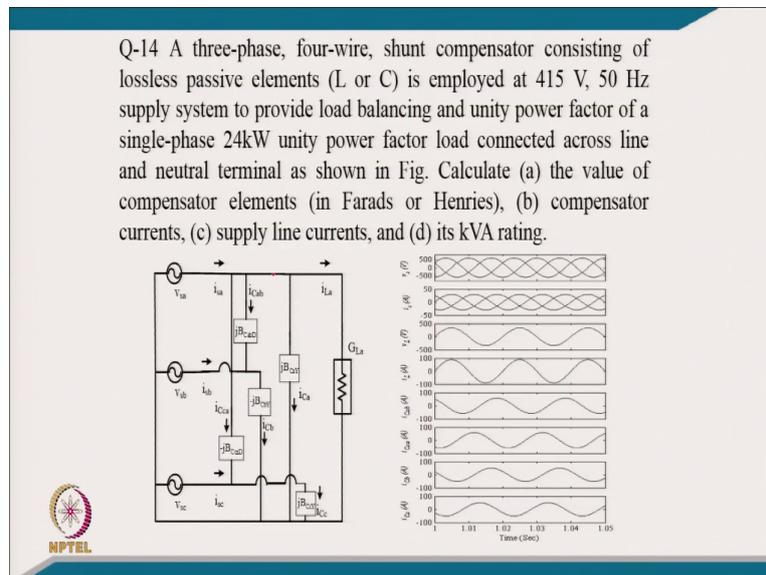
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B_{Ca}=0.2613 mhos, B_{Cb}= -0.2011mhos, B_{Cc}=0.2011 mhos.
Values of elements of compensator, C_{Ca}= B_{Ca}/ω = 831.74 µF, L_{Cb}= 1/($B_{Cb}\omega$)=15.12 mH, C_{Cc}= B_{Cc}/ω= 640.12 µF.
(c) The compensator phase currents,
I_{Ca}=$V_{sp}*B_{Ca}$= 62.60 $\angle90°$A, I_{Cb}=$V_{sp}*B_{Cb}$ = 48.19$\angle150°$A, I_{Cc}=$V_{sp}*B_{Cc}$ = 48.19 $\angle210°$A.
(d) The compensator VA rating, Q_C= V($|I_{Ca}|+|I_{Cb}|+|I_{Cc}|$) = 38091.608 VAR = 38.09 kVAR.

I mean it will be your capacitance value will be 831.74 micro Farad, and inductance for line cb will be your 15.1 milli Henry, and line cc will be 64 say 401.2 micro Farad. And compensator current putting the value it comes like a similarly 48.19 am ampere at the angle of 150 degree. Similarly, for c phase, it comes 48.19 at the angle of 240 degree.[FL] Compensator VA rating V into absolute value of the I mean current will be 38091.608 VAR, or 38.09 kVAR.

Q-14 A three-phase, four-wire, shunt compensator consisting of lossless passive elements (L or C) is employed at 415 V, 50 Hz supply system to provide load balancing and unity power factor of a single-phase 24kW unity power factor load connected across line and neutral terminal as shown in Fig. Calculate (a) the value of compensator elements (in Farads or Henries), (b) compensator currents, (c) supply line currents, and (d) its kVA rating.

The another example of four-wire system[FL] example number-14, a three-phase four-wire, shunt compensator consisting of lossless passive element is implied at 415 volt, 50 Hertz supply system to avoid load balancing and unity power factor of a single-phase load of 24 kilowatt unity power factor load connected across line and neutral as shown typically here on the resistive load.

Calculate the value of compensator element, compensator current, and supply line current, and its kVA rating.[FL] Here we are typically providing the load balancing and power factor correction also in spite of single-phase line to neutral load.

Solution: Given that, the supply phase voltage, V_{sp}=415/√3 V=239.6 V, frequency of the supply, f=50 Hz, a single-phase 24 kW unity power factor load connected across line and neutral terminal.

The load impedance/phase, Z_{La} =2.392 Ω. The load admittance/phase, Y_{La}= G_{La} +jB_{La} = 0.418+j0 mhos.

It requires two set of susceptances one in star connected (Y) and other set of delta connected across the lines to eliminate neutral current and load balancing.

(a) Compensator star connected susceptances for neutral current and power factor correction,

B_{CaY}=-B_{La}+(G_{Lb}-G_{Lc})/√3, B_{CbY} = -B_{Lb}+(G_{Lc}-G_{La})/√3, B_{CcY}=-B_{Lc}+(G_{La}-G_{Lb})/√3

Substituting the values,

B_{CaY} = 0.0 mhos, B_{CbY}= -0.241 mhos, B_{CcY}= 0.241 mhos.

Values of elements of star connected compensator,

C_{CaY}= B_{CaY}/ω = 0.0 μF, L_{CbY}= 1/(B_{Cb}ω) = 13.188 mH, C_{CcY}= B_{CcY}/ω = 768.291 μF.

[FL] Coming to the solution that given the supply voltage of phase voltage from line voltage 415 by root 3 236.9 volt and frequency of 50 Hertz a single-phase load of 24 kilowatt at unity power factor connector across the line a to neutral and we can find out the load virtually impedance that comes to 2.392 ohm because it is a resistive load you of because of unity power factor.

And we can find out admittance here[FL] the conduct conductance part only there 0.18, and but the susceptance part is 0 because there is no reactive power in the load.[FL] it requires two sets of susceptances. One is star connector, another in delta connector sets across the line to eliminate the neutral. And compensator star connected susceptances for neutral current and power factor correction I mean from these derived relation we can get the value.

And here for a phase, it comes 0 because it is a resistive load,[FL] there is no need of any compensator element. Across the bc, it comes 0.241 ohm; and for ca it comes 0.241 ohm. And value of element is star connected compensator coming from this value is 0 micro Farad for obviously for a phase; for b phase inductance of 13.18 micro milli Henry; and capacitance across the c to ground it will be neutral, it will be 768.291 micro Farad.

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Compensator delta connected susceptances,
$B_{CabD} = 2(G_{La} - G_{Lb})/3\sqrt{3}$, $B_{CbcD} = 2(G_{Lb} - G_{Lc})/3\sqrt{3}$, $B_{CcaD} = 2(G_{Lc} - G_{La})/3\sqrt{3}$
Substituting the values,
$B_{CabD} = 0.161$ mhos, $B_{CbcD} = 0.0$ mhos, $B_{CcaD} = -0.161$ mhos.
Values of delta connected compensator elements,
$C_{CabD} = B_{CabD}/\omega = 512.194$ µF, $L_{CcaD} = 1/(B_{CcaD}\omega) = 19.782$ mH.

(b) The compensator star connected phase currents,
$I_{Ca} = V_{sp} * B_{CaY} = 0.0$ A,
$I_{Cb} = V_{sp} * B_{CbY} = 57.831$ A,
$I_{Cc} = V_{sp} * B_{CcY} = 57.831$ A.
The compensator delta connected phase currents,
$I_{Cab} = \sqrt{3} V_{sp} * B_{CabD} = 66.778$ A,
$I_{Cbc} = \sqrt{3} V_{sp} * B_{CbcD} = 0.0$ A,
$I_{Cca} = \sqrt{3} V_{sp} * B_{CcaD} = 66.778$ A.

And compensators which is delta connected susceptances from this relation which we derived in the last class we can put the value. And we get the of course, these all susceptances. And the value of delta connected element as a capacitance 400, 512.194 micro Farad; inductance across the typically here 19.7282 milli Henry.

And from this we can find out the star connected compensator element currents from this relation. And the star connected compensator for a phase have a 0 current because there is no

compensator element. And for b and c, it comes 57.831 ohm. Similarly, for delta connected compensator for line bcD is 0; and for   other two, it come 66.77 equal currents like.

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(c) Supply line currents after compensation,

$I_{sa} = (V_{sp}G_{La}/3) \angle 0° = 33.389 \angle 0°$ A,

$I_{sb} = (V_{sp}G_{La}/3) \angle -120°$ A $= 33.389 \angle -120°$ A,

$I_{sc} = (V_{sp}G_{La}/3) \angle 120°$ A $= 33.389 \angle 120°$ A.

(d) The compensator VA rating,

$Q_C = V_{sp}(|I_{Ca}| + |I_{Cb}| + |I_{Cc}|) + \sqrt{3}V_{sp}(|I_{Cab}| + |I_{Cbc}| + |I_{Cca}|)$

$= 27712.657 + 55425.740$ VA $= 83.138$ kVA.

And now we can find out typically the supply current after the compensation from this relation, it comes 33.389, and with the angle of minus 120 degree and plus 120 degree for balance load at unity power factor on the supply system. And the compensator element, we can find out with the absolute current multiply the phase voltage.

And from this for star connector and for delta connector, it comes after addition 83.138 kVA.[FL] In this case what we have done, we have taken a load balancing, we have taken a power factor correction I mean as well as neutral current elimination.[FL] All three functions we did with this compensator like.

Q.15 A three-phase, four-wire, shunt compensator consisting lossless passive elements (L or C) is used at 415V, 50 Hz supply system to provide load balancing and power factor correction of a single-phase 25 kVA, 0.8 lagging power factor load connected across line and neutral terminal. Calculate (a) supply line currents, (b) the value of compensator elements (in Farads or Henries), (c) compensator currents, and (d) its kVA rating.

Coming to the typically a numerical example number 15, a three-phase four-wire, shunt compensator consisting of lossless passive element is used at 415 volt, 50 Hertz supply system to provide load balancing a power factor correction of single-phase load of 25 kVA, 0.8 lagging power factor load connected across line to neutral.

And calculate a, supply line current, the value of compensator element, and compensator current, and its kVA rating to provide the load balancing and power factor correction means to realize the unity power factor load.

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Schematic diagram and performance waveforms
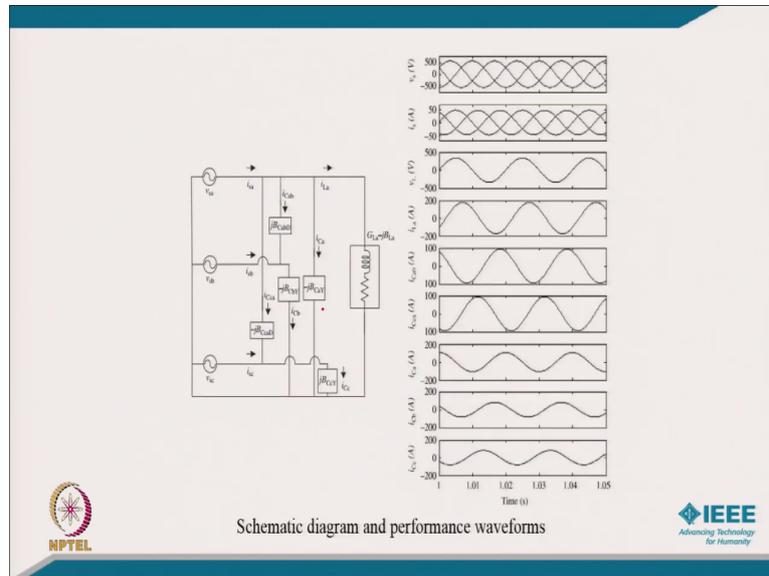
And this is the circuit of the configuration that we have a typically here I mean for realizing it as a 5 element I mean otherwise the solution will not be needed.[FL] We already discussed earlier when we were discussing the condition[FL] we take a 5 element I mean 5 elements virtually delta 3A and star connection only 2 elements, so it becomes then unique solution because there are 5 elements and there are 5 equations like.

Solution: Given that, the supply phase voltage, Vsp=415/√3 V=239.6 V, frequency of the supply, f=50 Hz, a single-phase 25 kVA, 0.8 lagging power factor load connected across line and neutral terminal. The load impedance/phase, Z_{La} =1.837+j1.377 = 2.29 ∠36.87° Ω. The load admittance/phase, Y_{La}= 0.3484− j0.2613 = 0.435∠-36.87° mhos.

It requires two set of susceptances one in star connected (Y) and other set of delta connected across the lines to eliminate neutral current and load balancing.

a) Supply line currents after compensation,
I_{sa}=($V_{sp}G_{LT}$/3) ∠0°A, I_{sb}=($V_{sp}G_{LT}$/3) ∠-120°A,
I_{sc} =($V_{sp}G_{LT}$/3) ∠120°A.
I_{sa}=($V_{sp}G_{LT}$/3) ∠0°A = 27.826 ∠0°A, I_{sb}= 27.826 ∠-120°A,
I_{sc}= 27.826 ∠120°A.
b) Compensator star connected susceptances for neutral current and power factor correction,

And putting the value of course I mean in this relation given that the supply voltage is V sp 415 by root 3, and frequency of supply 50 Hertz, and single-phase load of 25 kVA, 0.8 lagging power factor connected across line to neutral of a phase.[FL] We can find out load impedance from this relation it comes 2.29 at the angle of 36.87 ohm.

And load admittance one reciprocal of this 0.435 at the angle of minus 36.87 ohm. It requires two set of susceptances; one again in star, another in delta across the line to eliminate the neutral current and load balancing. And typically after supply current after compensation is a balance current, and it comes 29 point after putting the value 29.114 at the angle of 0, then minus 120 degree and plus 120 degree as a balance current. And compensator star connected susceptance of neutral current and power factor correction.

The value after keeping the relation I mean these comes typically the capacitance comes to 831.74 micro Farad. And for inductor for line bY, it comes 15.83 milli Henry; and line c, it comes 64; 640.12 micro Farad. Assembling compensator for keeping in this relation for delta connected capacitance.

[FL] The value comes off typically line ab, it comes like a 4 426.85 micro Farad; and the inductance for line ca, it comes 23.74 milli Henry. And the compensator is the star connected phase current putting the value this it comes 62.61 ampere; and for line cb, it comes 48.18 ampere; and line ca, it comes 48.184 ampere.

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The compensator delta connected phase currents,
$I_{Cab} = V_s * B_{CabD} = 55.65$ A, $I_{Cbc} = V_s * B_{CbcD} = 0.0$ A., $I_{Cca} = V_s * B_{CcaD} = 55.65$ A.

(d) The compensator VA rating,
$Q_C = V_s(|I_{Ca}| + |I_{Cb}| + |I_{Cc}|) + \sqrt{3} V_s(|I_{Cab}| + |I_{Cbc}| + |I_{Cca}|)$
$= 38091.13 + 46189.50$ VAR $= 84280.63$ VAR $= 84.28$ kVAR.

And the compensator delta connected putting the value,[FL] it comes for line ab 55.65 ampere; and for bc, it is typically 0 because there is no element; and line ca, it is typically 55.65 ampere. And the compensator VA rating the phase voltage multiplied the three-phase current for star equivalent, and the line voltage multiplied the absolute value of all the three line current of compensator.[FL] Putting the value of this, it comes like a typically 84.28 kVAR compensator rating like.

Q.16 A three-phase, four-wire, unbalanced load has an impedance (Z_a=5.0+j2.0 pu) connected between phase a and neutral terminal with an input line-line voltage of 415V, 50Hz, AC supply system and a base impedance of 5.3 ohms per phase. It is to be realized as a three-phase balanced unity power factor load on three-phase supply system using a shunt compensator consisting lossless passive elements (L or C). Calculate (a) the value of compensator elements (in Farads or Henries), (b) supply line currents, (c) compensator currents, (d) its kVA rating, and (e) equivalent per phase resistance (in ohms) of the compensated load.

Coming to another example say number 16 in four-wire system, a three-phase, four-wire, unbalanced load has an impedance of Z a equal to 5.0 plus j 2 ohm connected between phase a to neutral terminal with the input line voltage of 415 volt, AC supply system and a base impedance 5.3 ohms per phase.

And it to be realized as a balance three-phase unity power factor load on the three-phase supply system using a shunt compensator consisting lossless passive element. Calculate, a, the value of compensator element; supply, b, supply level current; c, compensator current; d, kVA rating; and e, equivalent per phase of the compensator load.

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Schematic diagram and performance waveforms
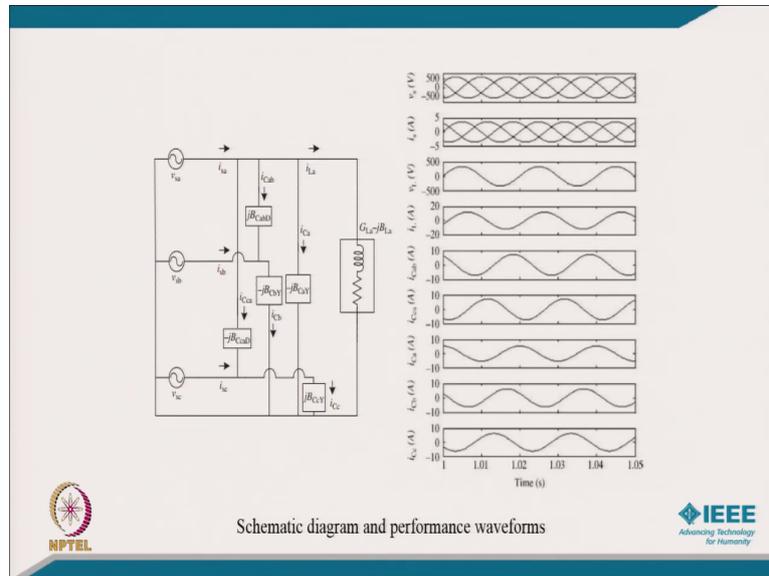
So, this is the network here again we are taking only five element, all three dealt typically all three star element; in delta we are taking two element.[FL] One current of delta element will be 0 I mean like or so. And after getting the solution or getting the value this wave form are run from typically putting the value in the circuit network.

Solution: Given that, the supply phase voltage, V_{sp}=415/$\sqrt{3}$ V=239.6 V, frequency of the supply, f=50 Hz,a single-phase impedance (Z_{La}=5.0+j2.0 pu) connected between phase a and neutral terminal with a base impedance of 5.3 ohms per phase.

The load impedance/phase, Z_{La} =(26.5000 +j10.6000) = 28.54 $\angle$21.80° Ω.

The load admittance/phase, Y_{La}= 0.0325 – j 0.0130 = 0.035$\angle$-21.80° mhos.

It requires two set of susceptances one in star connected (Y) and other set of delta connected across the lines to eliminate neutral current and load balancing.

(a) Compensator star connected susceptances for neutral current and power factor correction,

B_{CaY}=-B_{La}+(G_{Lb}-G_{Lc})/$\sqrt{3}$, B_{CbY}=- B_{Lb}+(G_{Lc}-G_{La})/$\sqrt{3}$, B_{CcY}=-B_{Lc}+(G_{La}-G_{Lb})/$\sqrt{3}$ Substituting the values,

B_{CaY}=0.0130 mhos, B_{CbY}=-0.0188 mhos, B_{CcY}=0.0188 mhos.

[FL]Coming to the solution. Given that supply voltage of 415 volt by root 3 that is the phase voltage 239 because it is a star network, and frequency supply say some 50 Hertz, a single-phase impedance of the load is 5.0 and plus 8 2 per unit connected between phase a two neutral with a base impedance of 5.3 ohm per phase.[FL] We can find out the load impedance.

And then the load admittance and require two set of star connected compensator; one in star connector, another in delta connection. And compensator we have considered for star connection for the neutral current composition, power factor correction. And the value for star connected compensator comes about the typically a value of this.

Values of elements of star connected compensator,
$C_{CaY} = B_{CaY}/\omega = 41.42\ \mu F$, $L_{CbY} = 1/(B_{CbY}\omega) = 169.5$ mH, $C_{CcY} = B_{CcY}/\omega = 59.78\ \mu F$.
Compensator delta connected susceptances,
$B_{CabD} = 2(G_{La}-G_{Lb})/3\sqrt{3}$, $B_{CbcD} = 2(G_{Lb}-G_{Lc})/3\sqrt{3}$, $B_{CcaD} = 2(G_{Lc}-G_{La})/3\sqrt{3}$
Substituting the values,
$B_{CabD} = 0.0125$ mhos, $B_{CbcD} = 0.0$ mhos, $B_{CcaD} = -0.0125$ mhos.
Values of delta connected compensator elements, $C_{CabD} = B_{CabD}/\omega = 39.85\ \mu F$, $L_{CcaD} = 1/(B_{CcaD}\omega) = 254.64$ mH.
(b)The compensator star connected phase currents,
$I_{Ca} = V_{sp}*B_{CaY} = 3.115$ A, $I_{Cb} = V_{sp}*B_{CbY} = 4.5$ A, $I_{Cc} = V_{sp}*B_{CcY} = 4.5$ A.

The compensator delta connected phase currents,
$I_{Cab} = V_{sp}*B_{CabD} = 5.188$ A, $I_{Cbc} = V_{sp}*B_{CbcD} = 0.0$ A, $I_{Cca} = V_{sp}*B_{CcaD} = 5.188$ A. .

And from this, we can find out the capacitance for a phase 41.43 micro Farad. And inductance for b, 169.5 milli Henry; and for phase c, it comes 59.78 micro Farad. And delta connected compensator we have of course typically compensator for 2,[FL] it comes like a line ab, it comes 0.125 mho; and B bc, it 0, and your ca 0.0152 mho. And getting the value of this an element capacitance come 39.85 mega Farad; and line ca, it comes to 54.64.

And of course, there is no element across the your bc line,[FL] compensator the star connected phase current by putting the value of your susceptances and voltage we get the three three-phase current 31.5 ampere. Then for b phase, it comes 4.5 ohm; at c phase, it comes 4.5. And for delta of course we get the four one, we get that 0; other 5.18 and then 5.188 ampere.

(c) Supply line currents after compensation,

$I_{sa}=(V_{sp}G_{LT}/3)\angle0°A$, $I_{sb}=(V_{sp}G_{LT}/3)\angle-120°A$,

$I_{sc}=(V_{sp}G_{LT}/3)\angle120°A$.

$I_{sa}=(V_{sp}G_{LT}/3)\angle0°A=2.598\angle0°A$, $I_{sb}=2.598\angle-120°A$,

$I_{sc}=2.598\angle120°A$.

(d) The compensator VA rating,

$Q_C=V_s(|I_{Ca}|+|I_{Cb}|+|I_{Cc}|)+\sqrt{3}V_s(|I_{Cab}|+|I_{Cbc}|+|I_{Cca}|)=2902.75+4306.04$

VAR=7208.79 VAR=7.209 kVAR.

(e) Equivalent per phase resistance (in ohms in star connection) of the compensated load,

$G_{eq}=(G_{La}+G_{Lb}+G_{Lc})/3=0.010843$ ℧, $R_{eq}=1/G_{eq}=92.308$ Ω

And then we can get the all three-phase supply current which is a balance current putting all these value,[FL] we get the balance current 2.598 ohm at the angle of 0, then minus 120 degree and for c phase at plus 120 degree. And compensator VA rating of course, the phase voltage the current of a star connected compensator line voltage and delta connected current compensator, and it comes addition of both it is a 7.02 kVAR compensator.

An equivalent per phase resistance in star connection that comes to be like a sum of all the conductance by conductance by 3, and it comes typically in resistance say 92.308 ohm.

Q.17 A three-phase, four-wire, unbalanced load (Za=3.0+j1.0 pu, Zb=4.0+j2pu and Zc=6+j1.2 pu) has an input line-line voltage of 415V, 50Hz, AC supply and base impedance of 5.3 ohms per phase. It is to be realized as a three phase balanced unity power factor load on three-phase supply system using a shunt compensator consisting lossless passive elements (L or C). Calculate (a) the values of compensator elements (in Farads and Henries) and (b) equivalent per phase resistance (ohms) of compensated load.

[FL]In coming to another example of 17, a three-phase, four-wire, unbalanced load of Z a equal to 3.0 ohm plus j 1 sorry per unit, and Z b 4 per unit plus j 2 per unit, Z c 6 point 1.2 per unit has a line to line voltage 415 volts, AC supply and base impedance of 5.3 per phase.

And it is realized as a three-phase balanced unity power factor load on the three-phase supply system using a shunt compensator consisting lossless passive element. And calculate the value of compensator element, and the equivalent per phase resistance of the compensated load.

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Schematic diagram and performance waveforms

And this is the network. Again we have a 5 elements here. For star connection, we all 6 element; we have a 3 delta and 3 star connection and for eliminating the neutral current and power factor correction and balancing the load like I mean or [FL].

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Solution: Given that, the supply phase voltage, $V_s=415/\sqrt{3}$ V=239.6 V, frequency of the supply, f=50 Hz, an unbalanced load ($Z_{La}=3.0+j1.0$ pu, $Z_{Lb}=4.0+j2.0$ pu and $Z_{Lc}=6+j1.2$ pu) has an input line-line voltage of 415V, 50Hz, AC supply and base impedance of 5.3 ohms per phase.

The load impedances/phase, $Z_{La} = (15.9000 + j5.3000)$ Ω, $Z_{Lb} = (21.2000 +j10.6000)$ Ω, $Z_{Lc} = (31.8000 + j6.3600)$ Ω.

The load admittance/phase, $Y_{La} = (0.0566 - j\,0.0189)$ mhos, $Y_{Lb} = (0.0377 - j\,0.0189)$ mhos, $Y_{Lc} = (0.0302 - j\,0.0060)$ mhos.

It requires two set of susceptances one in star connected (Y) and other set of delta connected across the lines to eliminate neutral current and load balancing

(a)Compensator star connected susceptances for neutral current and power factor correction,

$B_{CaY}=-B_{La}+(G_{Lb}-G_{Lc})/\sqrt{3}$, $B_{CbY}=-B_{Lb}+(G_{Lc}-G_{La})/\sqrt{3}$, $B_{CcY}=-B_{Lc}+(G_{La}-G_{Lb})/\sqrt{3}$ Substituting the values,

$B_{CaY}= 0.0232$ mhos, $B_{CbY}= 0.0036$ mhos, $B_{CcY}= 0.0169$ mhos.

Values of elements of star connected compensator,

[FL] That is typically the solution coming to supply voltage of phase voltage of two to 415 by root 3 that is 239. And then taking a impedance of this unbalanced load Z La, Z Lb, Z Lc in per unit, and multiply the base impedance we get the actual ohmic impedance. And from that we get the admittances.

And after that we get the it require two set of susceptances one in star connection, other in delta connection across the line to eliminate the neutral current and load balancing. And compensator in star connector we consider all the three elements, and we get the typical value of these susceptances.

And then we are getting a capacitance for a phase 73.83 micro Farad; line B B to neutral, we get 11.063 micro Farad; and c, we get 53.79 micro Farad. And of course, delta connected compensator we connect only typically the, I mean these relation we get the value of this.

And we get the capacitance value 23.237 micro Farad; and for bc we get 9.23 micro Farad; and c we get typically inductance 315.158 milli. An equivalent per phase resistance after getting conductance a equivalent divide by 3 with that we get equivalent to a star and resistance comes per phase equivalent in star connected mode is come 24.08 ohm.[FL] We provide the load balancing as well as neutral current elimination, and unity power factor operation in that case.

Q.18 A 3-phase AC supply system has a line voltage of 415V at 50Hz and feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase after which a unbalanced isolated neutral and star connected load having Z_a=12 ohms, Z_b=24 ohms and Z_c=36 ohms is connected. Calculate (a) the voltage drop across a source impedance and (b) the voltage across the load if a shunt compensator consisting lossless passive elements (L or C) is used to (c) balance at upf and then (d) to raise the voltage to same as input voltage (415V), in both cases.

[FL] Coming to another example-18, a 3-phase ac supply system have a line voltage of 415 volt at 50 Hertz and feeder impedance point five ohm resistance and 2.5 ohm inductive reactance after which a unbalance isolated star connected load having a Z equal to 12 ohm, Z b equal to 24 ohm, and Z c 36 ohm is connected.

Calculate, a, the voltage drop across the source impedance; the voltage across the load if shunt compensator consisting lossless passive element is used; and balance at unity power factor and then raise the voltage same as the 415 volt in both the cases.[FL]We are having a power factor resistance as well as load balancing then power factor correction.

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Schematic diagram and performance waveforms
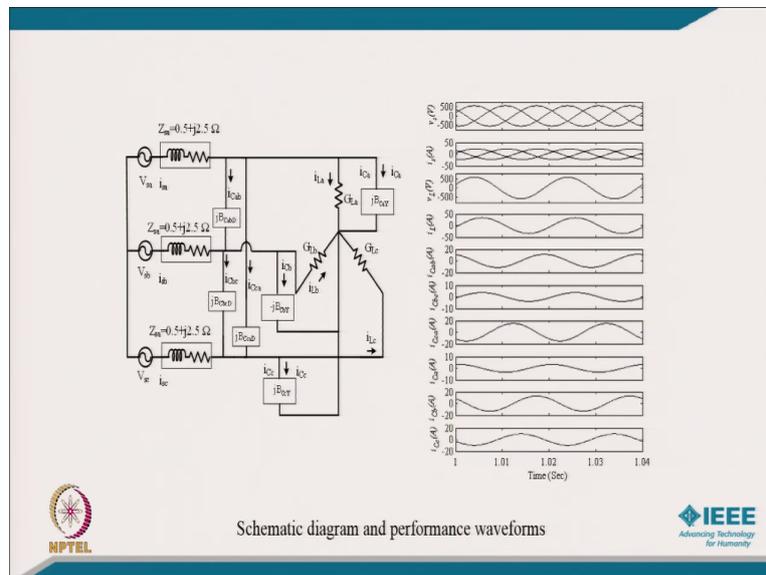
And after that the voltage regulation same as the this.[FL] We have a typically a star connected load and we have a logistics element of the compensator I mean after the source impedance.[FL] We will be having a power factor correction, load balancing, and then after that we will have a voltage regulation.[FL]

After getting all those relation, these are the typically after design we have plotted the waveform I mean for the with those compensator values, and becomes as a balance load unity power factor as well as voltage regulation also.

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Solution: Given that, the supply phase voltage, V_{sp}=415/√3 V=239.6 V, frequency of the supply, f=50 Hz, a unbalanced isolated neutral and star connected load having Z_{La}=12 ohms, Z_{Lb}=24 ohms and Z_{Lc}=36 ohms is connected with feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase.

Load admittances/phase, Y_{La}= 0.0833 mhos, Y_{Lb}= 0.0417 mhos, Y_{Lc}= 0.0278mhos.

(a) For power factor corrections and load balancing and neutral current elimination, the equivalent load conductance in star configurations is as,

G_{LY}=(G_{La}+G_{Lb}+G_{Lc})/3= 0.0509 mhos, R_{LY}=19.6364 ohms.

Total impedance across the supply, Z_{LT}= 20.2910 ohms.

Supply current, I_s=V_{sp}/Z_{LT}=239.6/20.2910 =11.8082 A.

The voltage across the source impedance, V_{zs}=$I_s Z_s$=30.1052· V.

The voltage across the load impedance, V_{ZL}= Z_{LY}*I_s= R_{LY}*I_s= 231.8707 V

So, coming to the solution given that the supply voltage is line voltage 415 by root 3 is the phase voltage 239.6, 50 frequency of 50 Hertz, and unbalanced isolated neutral star connector having a Z b, Z c connected this. And load admittance you can get from this impedances, and for power factor correction load balancing the neutral elimination.

The star equivalent load conductance in a star configuration comes out for balance load and where the equivalent resistance in the star connection comes 19.6364 ohm. And total impedance across the supply now we can find out which is some of the resistance plus the source impedance,[FL] it comes like a supply line current from which we can get.[FL] We can get the drop after the balancing this voltage drop across 30.1052 volt.

And voltage across the load impedance after the balancing comes only 231.87 in place of 239.6[FL] it means this is around 8 voltage the drop in the source impedance reduction in the

8 voltage, but the drop in the source impedance is much higher because of the angle difference like or so.

The compensator star connected susceptances for neutral current and power factor correction,

$B_{CaY} = -B_{La} + (G_{Lb} - G_{Lc})/\sqrt{3}$, $B_{CbY} = -B_{Lb} + (G_{Lc} - G_{La})/\sqrt{3}$, $B_{CcY} = -B_{Lc} + (G_{La} - G_{Lb})/\sqrt{3}$

Substituting the values,

$B_{CaY} = 0.0080$ mho, $B_{CbY} = -0.0321$ mho, $B_{CcY} = 0.0241$ mho.

Values of elements of star connected compensator are as,

$C_{CaY} = B_{CaY}/\omega = 25.524$ µF, $L_{CbY} = 1/(B_{CbY} * \omega) = 99.2$ mH, $C_{CcY} = B_{CcY}/\omega = 76.57$ µF.

Compensator delta connected susceptances are as,

$B_{CabD} = 2(G_{La} - G_{Lb})/3\sqrt{3}$, $B_{CbcD} = 2(G_{Lb} - G_{Lc})/3\sqrt{3}$, $B_{CcaD} = 2(G_{Lc} - G_{La})/3\sqrt{3}$

Substituting the values,

$B_{CabD} = 0.0160$ mho, $B_{CbcD} = 0.0053$ mho, $B_{CcaD} = -0.0214$ mho.

Values of delta connected compensator elements are as,

$C_{CabD} = B_{CabD}/\omega = 51.04$ µF, $C_{CbcD} = B_{CbcD}/\omega = 17.01$ µF, $L_{CcaD} = 1/(B_{CcaD} * \omega) = 148.9$ mH.

Compensated star connected susceptance of for neutral current compensator and power factor correction, these are for your star connected compensator. And putting the value of these all elements of the load, we get the value of capacitance for a phase to ground neutral 25.52 micro Farad.

The inductance between b and neutral, 92.2 milli Henry; and c to neutral it comes 75.57 micro Farad. And compensator for delta connected I mean these are the typical derived relation, and putting the value of this, we get the capacitance across line ab 51.04 ohm micro Farad; and capacitance across the bc, we get 17.01 micro Farad; and line c typically ca, it comes inductance 148.9 milli Henry.

(b) Let the substance of value B_{cv} mho is to be connected in parallel to the load to raise the load voltage equal to the input voltage ($V_L = V_S$). The basic equation to regulate the load voltage equal to input voltage is as,

$$|V_L| = |V_{sp}/[\{(R_s + jX_s) + 1/(G_L + jB_{cv})\}]| * |1/(G_L + jB_{cv})| = |V_{sp}|$$

Solving this equation, the value of B_{cv} is as,

$$B_{cv} = [X_S \pm \{\sqrt{X_S^2 - (X_S^2 + R_S^2)(2R_S G_L + R_S^2 G_L^2 + X_S^2 G_L^2)}\}]/(X_S^2 + R_S^2)$$

Substituting the values of $X_S = 2.5\ \Omega$, $R_S = 0.5\ \Omega$ and $G_L = 0.0509$ mhos and considering "-" sign in "±", for lower value of the compensator, the value of B_{cv} is as, $B_{cv} = 0.0138$ mho.

Value of capacitor (C) = $B_{cv}/\omega = 43.94\ \mu F$.

$Y_{LV} = (0.0509 + j0.0138)$ mho.

$Z_{LV} = (18.2923 - j4.9585)$ ohms.

$Z_{LT} = 18.9524$ ohms.

$I_s = V_{sp}/Z_{LT} = 12.6422$ A.

(i) The voltage across the source impedance, $V_{zs} = I_s * Z_s = 32.2314$ V.

(ii) The voltage across the load impedance, $V_{ZL} = Z_{LV} * I_s = 239.6004$ V.

And let the susceptance of value c v mho is connected across in parallel to the load to raise the voltage equivalent to V L equal to V S. And these equations of course, are derived per phase a per phase equivalent star connected load, the load voltage.[FL] This relation we already have the phase volt typically the voltage across the load per phase voltage should be equal to the, your supply voltage magnitude both same for Z volt regulation.

This is the typically the current calculation which is flowing in the line in star connected equivalent network multiplied the your load impedance along with the compensator, and from which we can get the compensator element for zero voltage regulation in terms of so typically the source impedance R S and X S as well as the load conductance and here the V cb..

[FL] After putting the value of X S equal to 2.5, R S 0.5, and the G L of the load after the load balancing and power factor correction and considering minus sign for lower value of compensator it comes B cv 0.0138 mho, and capacitance value come 43.94 micro Farad.

And then we can find out the typically the load admittance after the voltage regulation, and load impedance after the voltage regulation. And Z LT becomes 18.9424 ohm. And current in the supply comes after voltage regulation 12.644 ampere. And voltage across the source impedance comes 32.23 volt. However, the load voltage comes same to 39.6 because it is a zero voltage regulation.[FL] It maintain same voltage as the source voltage after putting this compensator like or so.

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Q.19 A three-phase AC supply has a line-line voltage of 415V at 50Hz and feeder (source) impedance of 0.5 ohms resistance/phase and 2.5 ohms inductive reactance/phase after which a balanced star connected load Z=(24+j16) ohms/phase is connected. Calculate (a) the voltage drop across the source impedance and (b) the voltage across the load. If a shunt compensator consisting lossless passive elements (L or C) is used to raise the voltage to same as input voltage (415V), calculate (c) the value of compensator elements (in Farads or Henries), (d) compensator currents, (e) supply line currents, (f) its kVA rating.

[FL] Coming to another example-19, a three-phase AC supply has a line voltage of 415 50 Hertz and feeder impedance of 0.5 ohm resistance, and 2.4 inductive reactance after which a balanced star connected load of Z equal to 24 point j 16 ohm per phase is connected.

And calculate the voltage across the source impedance, voltage across the load if shunt compensator consisting of lossless passive element is used to raise the voltage same as the input voltage means zero voltage regulation, and value of compensated element, and compensated current, and supply current, and kVA rating of the compensator.

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Schematic diagram and performance waveforms
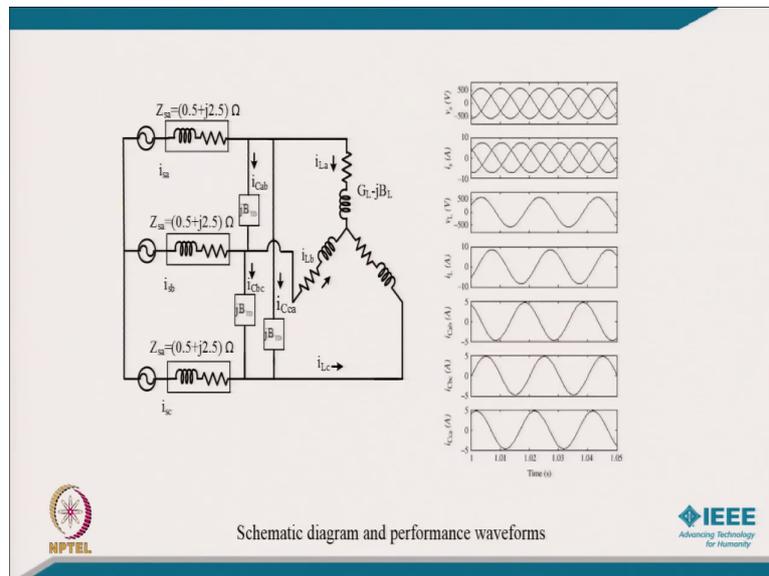
[FL] We have a source impedance which is balanced, but we have a here the typically a balanced load[FL] per phase it have a unity power factor compensation of the load. And after that we have to raise the voltage means zero voltage regulation we have to find out the solution. And this is the typical after getting solution with the element value which putting

that we got the balance voltage for unity power factor as well as typically for voltage regulation.

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Solution: Given that, the supply line to line voltage is V_{LL}=415V, hence phase to neutral voltage is, V_{sp}=415/√3 V=239.6 V, frequency of the supply, f=50 Hz, a unbalanced isolated neutral and star connected load having Z_{La}=(24+j16) ohms, Z_{Lb}=(24+j16) ohms and Z_{Lc}=(24+j16) ohms is connected with feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase.
Load admittances/phase, Y_{La}= 0.0288 - j0.0192 mhos, Y_{Lb}=0.0288 - j0.0192 mhos, Y_{Lc}= 0.0288 - j0.0192 mhos.
G_{LY}=(G_{La}+G_{Lb}+G_{Lc})/3=0.0288 mhos, R_{LY}=34.6667 Ohms.
A set of star connected substances in parallel to the load is required for power-factor correction of the value, B_{PF}=-B_{L}= 0.0192mhos.
(a) The voltage across the source impedance, V_{zs}=$I_s Z_s$=19.898 V.
The voltage across the load impedance, V_{ZL}=Z_{LY}*I_s = 225.117 V.
Let the substance of value B_{cv} mhos is to be connected in parallel to the load to raise the load voltage equal to the input voltage (V_L=V_S). The basic equation to regulate the load voltage equal to input voltage is as,

[FL] Coming to the solution given that the supply line voltage is 415 volt, hence the phase neutral voltage is 415 by root 3 that come 239.6, and frequency of 50 Hertz and unbalance as any star connected load typically of comes here typically this connected load connected to feeder this.

And load admittance comes this. And we can get a for load balancing the equivalent admittance in star connected which comes load resistance 34.66 ohm, a set of star connected susceptance in parallel to the load is required for power factor correction typically this susceptance.

And then the voltage across the load impedance is I s Z s 19.89. And voltage across the load comes after the load balance is say 225 point[FL] there is a voltage reduction here from 239.6 to 225 because of source impedance in spite the load is made balance. And after that a value of B cv for voltage regulation is connected in parallel to the load, so that the load voltage and your source voltage is made equal like.

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$|V_{sp}|=|V_{sp}/[\{(R_s+jX_s)+1/(G_L+jB_{cv})\}]|*|1/(G_L+jB_{cv})|=|V_{sp}|$
Solving this equation, the value of B_V is as,
$B_{cv}=[X_s\pm\{\sqrt{X_s^2-(X_s^2+R_s^2)(2R_sG_L+R_s^2G_L^2+X_s^2G_L^2)}\}]/(X_s^2+R_s^2)$
Substituting the values of $X_s=2.5$ Ω, $R_s=0.5$ Ω and $G_L=0.0288$ mho and considering "-" sign in "$\pm$", for lower value of the compensator, the value of B_{cv} is as, $B_{cv}=0.0069$ mhos, $B_T=B_{PF}+B_{cv}=0.0261$, $B_{TD}=(B_T/3)=0.0087$, $C_{BD}=B_T/3\omega=27.73$ μF(per phase for delta connected compensator).
(b) The compensator star connected phase currents are as follows,
$I_{Cab}=V_{ab}(jB_{TD})=415\angle30°*0.0087\angle90°=3.610\angle120°A$,
$I_{Cbc}=3.610\angle0°A$, $I_{Cca}=3.610\angle-120°$ A.
(c) Supply line currents are as follows,
$Y_{LV}=(0.0288+j0.0069)$ mhos.
$Z_{LV}=(32.837-j7.867)$ ohms.
$Z_{LT}=Z_{LV}+Z_s=33.767\angle-9.1461°$
$I_s=V_{sp}/Z_{LT}=239.6/33.767=7.096$ A.
(d) Its kVA rating, $Q_c=3|V_{LL}||I_{Cab}|=4494.45$ VAR = 4.494 kVAR.

And getting the solution for voltage regulation, this we are keeping the magnitude of the load voltage equal to the source voltage. And this is the calculation of typically source current and multiplied the impedance of the load along with the compensator.[FL] We get the compensator relation which we have discussed many time.

And putting the value of this, we get this typically the compensator I mean value of typically for voltage regulation. Then we add for all three for which I have used for power factor load

balancing. And from this, we get the compensator current value, admittance value, and we get the typically the load value[FL] we are able to get supply current here. After the compensation and kVA rating, we get equivalent to 4.494 kVAR like.
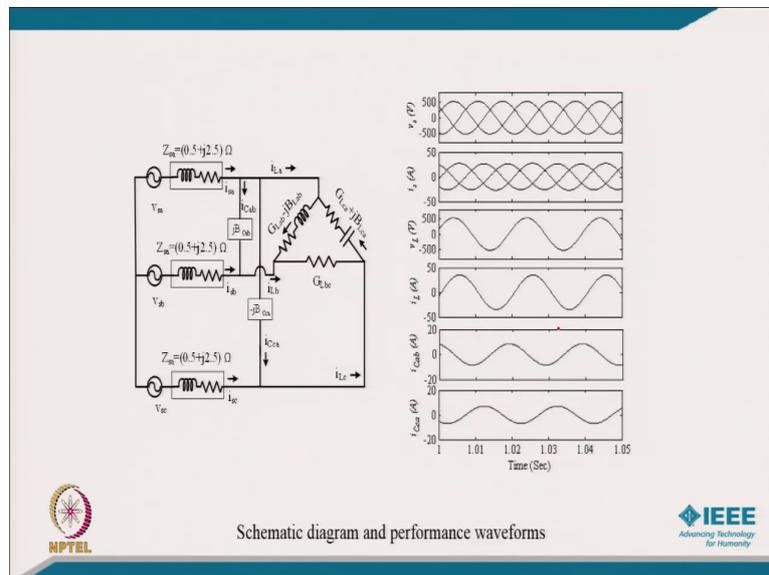
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Q.20 A 3-phase AC supply has a line voltage of 415V at 50Hz and feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase after which a unbalanced delta connected load having Z_{ab}=(20+j15) ohms, Z_{bc}=(25) ohms and Z_{ca}=(20-j15) ohms, is connected. If this load is to be realized as a balanced unity power factor load using a shunt compensator consisting lossless passive elements (L or C), calculate (a) supply line currents, (b) the value of compensator elements (in Farads or Henries), (c) compensator currents, (d) its kVA rating, and (e) power losses in source impedance after compensation.

[FL] Coming to the a so problem number 20, as an example a 3-phase AC supply system has a line voltage 415 volt and a feeder impedance of 0.5, 2.5 ohms inductive reactance after which a unbalanced data connector load is connected Z ab, Z bc and Z ca. And if load is to be realized as a balanced unity power factor using shunt compensator using this calculate supply current compensator current, and typically kVA rating and power loss in the source impedance after the compensation.

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Schematic diagram and performance waveforms

[FL] This is typically the unbalanced load delta connected source impedance there, and we are putting compensator typically for balancing this load.

Solution: Given that, the supply phase voltage, V_{sp}=415/$\sqrt{3}$ V=239.6 V, frequency of the supply, f=50 Hz a unbalanced delta connected load having Z_{ab}=(20+j15) ohms, Z_{bc}=(25) ohms and Z_{ca}=(20-j15) ohms is connected with feeder (source) impedance of 0.5 ohms resistance and 2.5 ohms inductive reactance/phase.

Load admittances, Y_{Lab}=(0.0320 - j0.0240) mhos, Y_{Lbc}=(0.0400) mhos, Y_{Lca}=(0.0320 + j0.0240) mhos,

Equivalent star connected conductance after compensation,

G_{LY}=G_{Lab}+ G_{Lbc}+ G_{Lca}= 0.1040 mhos, R_{LY}=1/G_{LY}=9.6154 ohms.

(a)supply line currents are as follows,

Z_{LT}=R_s+R_{LY}+jX_s=10.4197 ohms.

I_s=V_s/Z_{LT}=239.6/10.4197 = 22.9948 A.

The phase voltage across the load and compensator, V_{Lp}=R_{LY}*I_s=221.1043 V.

Line to line voltage across load is as V_{LL}=V_{LP}*$\sqrt{3}$ = 382.96 V.

(b) Compensator delta connected susceptances for load balancing and power factor correction,

Coming to the solution of typically of this of supply voltage with the phase voltage, and we have a compensator three-phase element. After this we can we got the conductance, and then for load balancing and unity power factor load. We get the typically a equivalent load resistance I mean which have to be in star connected, and we get the load impedance and then the typically the supply current.

And we can we got the load voltage now 221 which is reduced because of source impedance it is come twenty 221.10 for three in place of 239[FL] because of the source impedance is come. And line voltage we can find out, it is only 382.96 in place of 415 volt. And compensator delta connector susceptance load balancing putting of these value.

We get the capacitance across the ab 61.69; bc cb we get up to 0 milli Henry, there is no need; and another compensator 164.2 milli Henry. And we get the typically compensator current, and kVA rating absolute value of compensator and line voltage[FL] we get 6.82 kVAR. And power loss in the source impedance from 3 I s square R s,[FL] it comes 792 93.14 watt.

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[FL] With this I mean this passive shunt and series compensator I consider as a better alternative for power quality improvement to voltage and current based power quality mitigation. We are able to have a simple design.

High reliability compared to other options of power quality improvement especially in absence of harmonic voltage and current. It is considered to be beneficial to the designer, user, manufacturer and research engineers dealing with a power quality improvement in the distribution systems such as furnaces, traction system, rural supply system to balance consumer load, to reduce the negative sequence voltage at the PCC, and to improve the power factor and to improve the voltage regulation.

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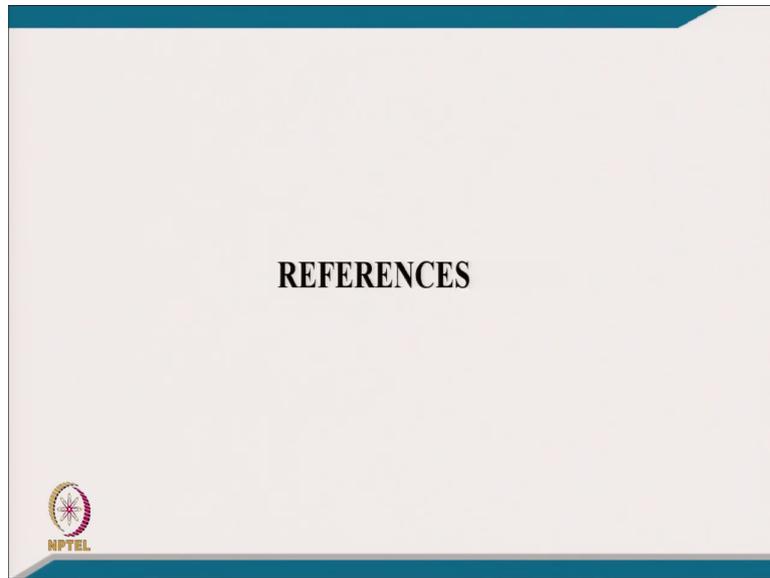
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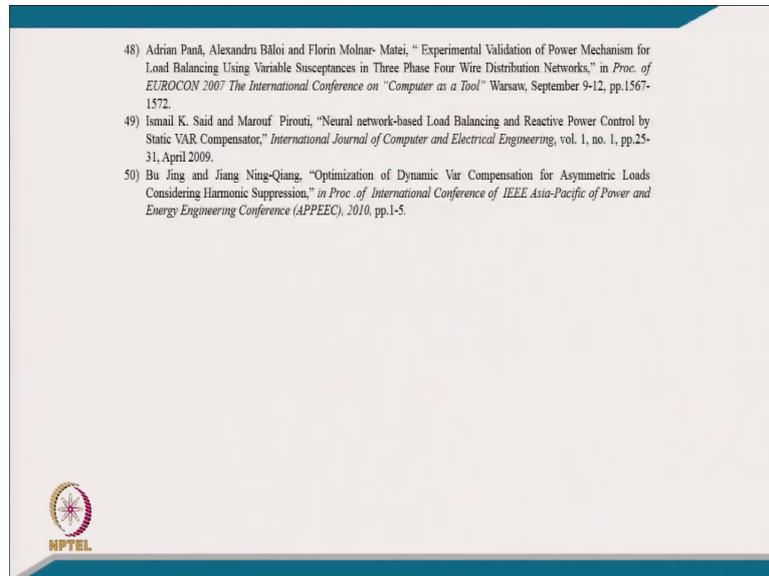
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And these are the some of the references I mean like typically. And thank you like.