12-Mavzu: Uch fazali zanjirlar.

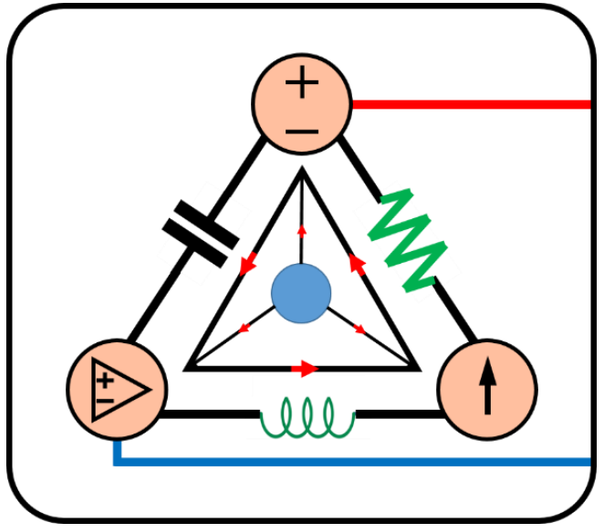
(12th Topic: Three-Phase Circuits.)

12-Mavzuning 2-qismi

(2nd part of the 12th Topic)

15-hafta uchun

For the 15th week



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12-Mavzu: Uch fazali zanjirlar.

(12th Topic: Three-Phase Circuits.)

O‘quv rejasi:

12.1. Umumiy tushunchalar.

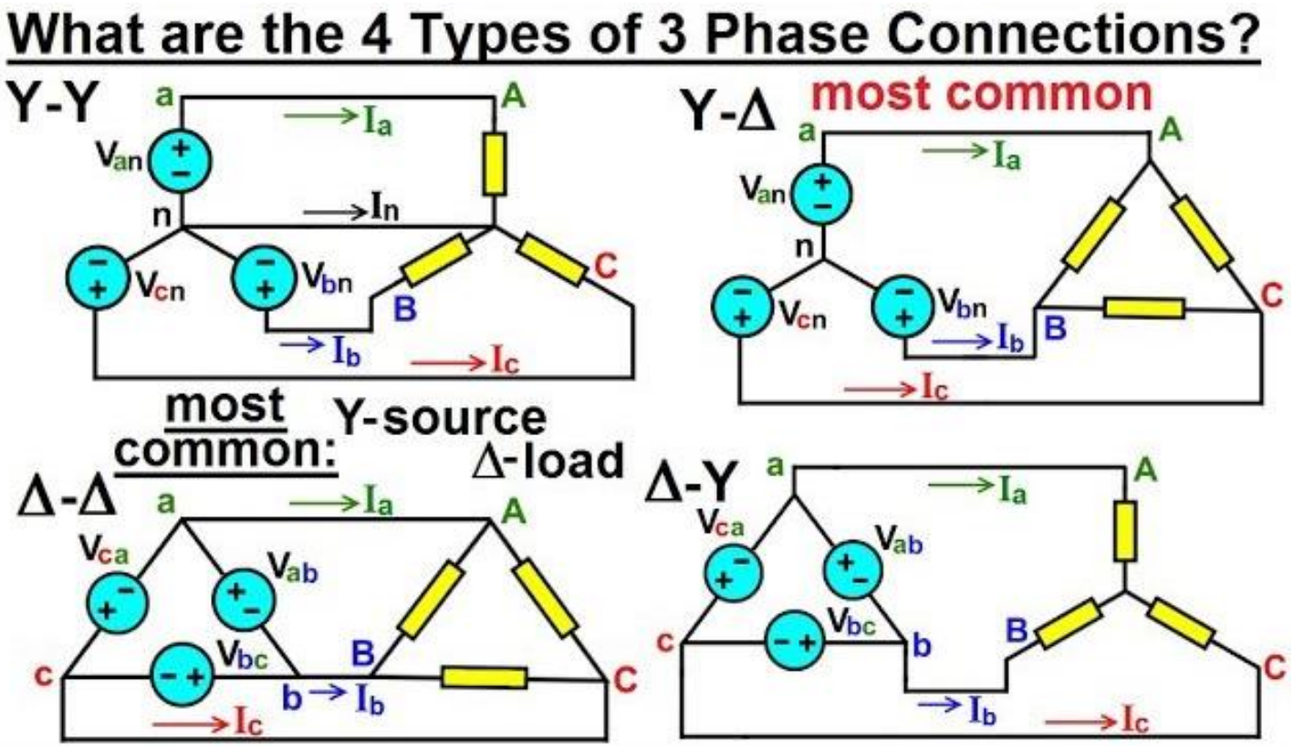
12.2. Muvozanatlangan uch fazali kuchlanishlar.

12.3. Muvozanatlangan yulduz-yulduz shakldagi (Y-Y) ulanish.

12.4. Muvozanatlangan yulduz-uchburchak shakldagi (Y-Δ) ulanish.

12.5. Muvozanatlangan uchburchak-uchburchak shakldagi (Δ-Δ) ulanish.

12.6. Muvozanatlangan uchburchak-yulduz shakldagi (Δ-Y) ulanish.



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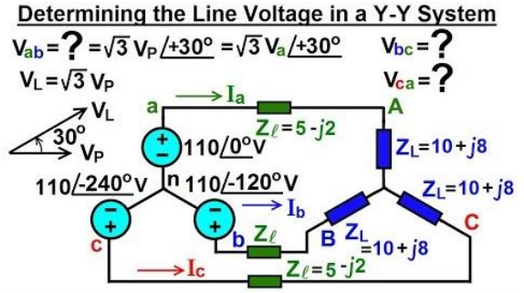

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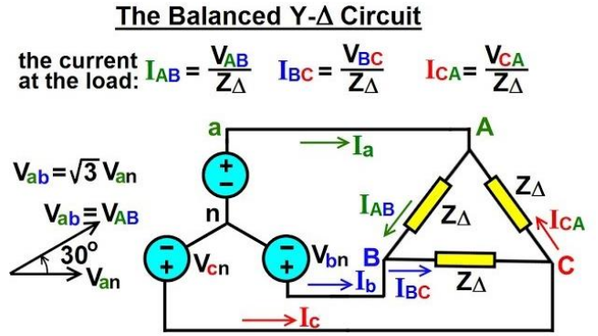

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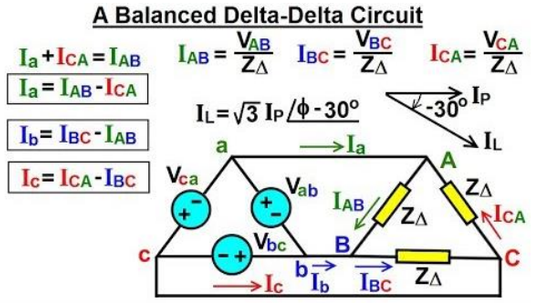

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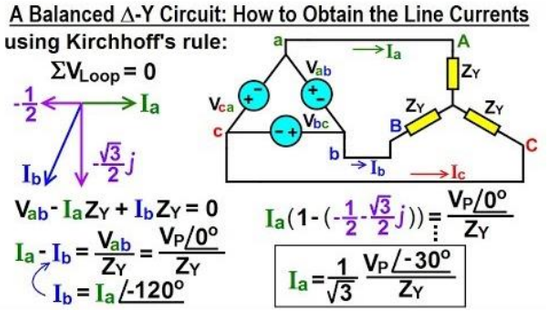
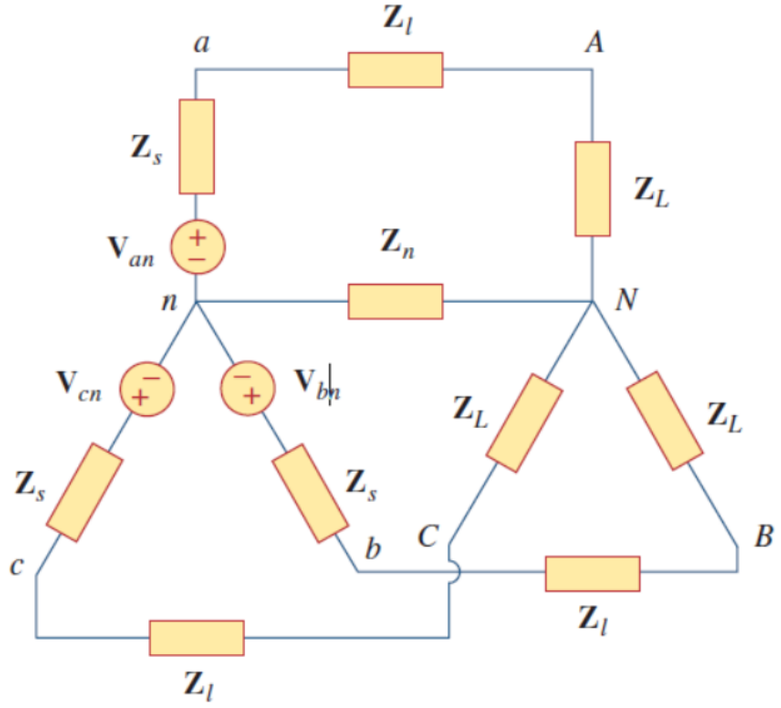


Photo source: [15] - https://i.ytimg.com/vi/nd-O1ifRhpI/hqdefault.jpg

12.3. Muvozanatlangan yulduz-yulduz shakldagi (Y-Y) ulanish.

Har qanday muvozanatli uch fazali tizim ekvivalenti qarshiliklari yulduz shaklida ulangan (Y-Y) tizimiga qisqartirilishi mumkin. Shu sababli, ushbu tizimni tahlil qilish barcha muvozanatlangan uch fazali tizimlarni hal qilish imkonini beradi.



12.10-rasm. Manba, tarmoq va yuklama impidenslarini ko‘rsatadigan muvozanatlangan Y-Y tizim.

Muvozanatlangan Y-Y tizimi – bu muvozanatli yulduz shaklida ulangan manba va muvozanatli yulduz shaklida ulangan yuklamadan iborat tizimdir.

$$\mathbf{Z}_Y = \mathbf{Z}_s + \mathbf{Z}_\ell + \mathbf{Z}_L$$

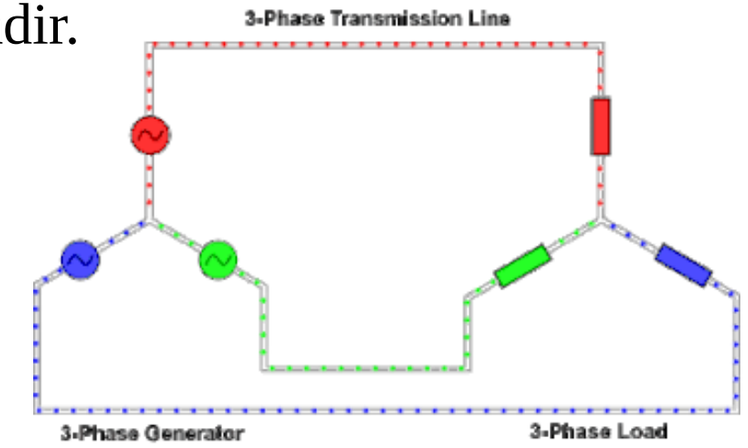
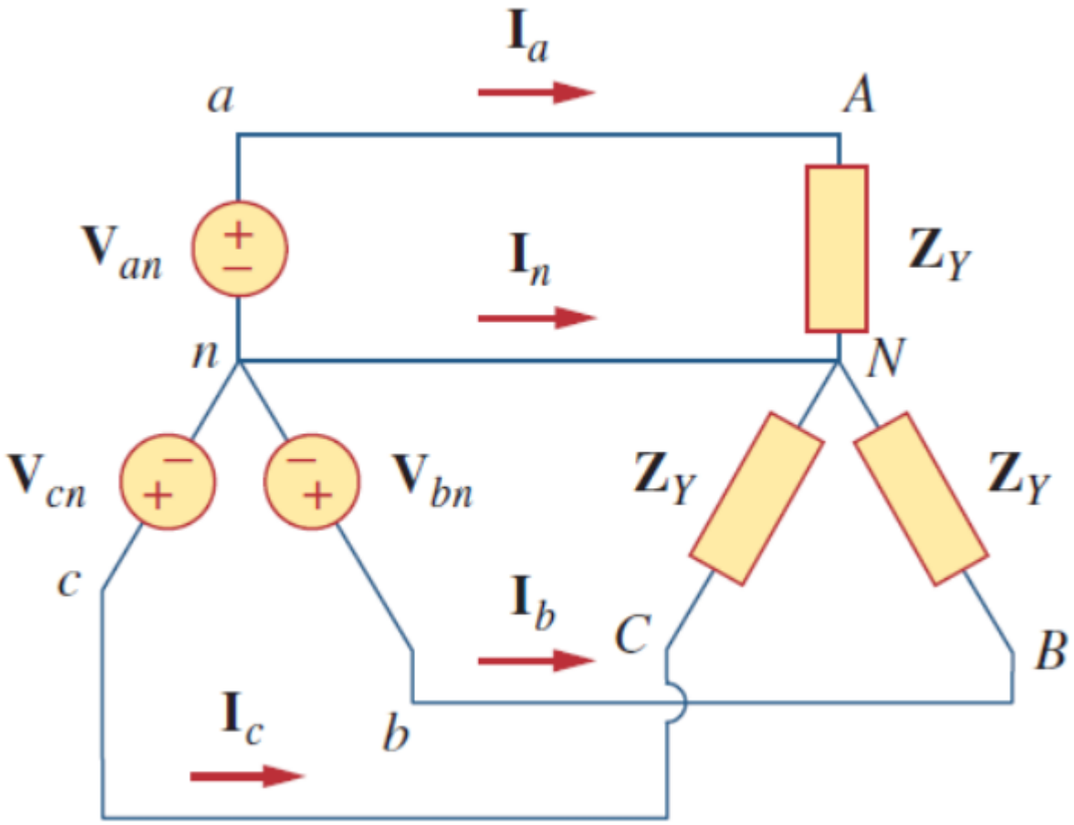


Photo source: [16] - https://upload.wikimedia.org/wikipedia/commons/thumb/4/48/3-phase_flow.gif/357px-3-phase_flow.gif

Z_s va Z_l ko‘pincha Z_L bilan solishtirganda juda kichikdir, shuning uchun hech qanday manba yoki tarmoq impidensi berilmasa $Z_Y = Z_L$ deb taxmin qilish mumkin.



Har qanday holatda, impidenslarni birlashtirib, 12.10-rasmdagi Y-Y tizimini 12.11-rasmda ko‘rsatilgandek soddalashtirish mumkin.

$$\mathbf{V}_{an} = V_p \angle 0°$$

$$\mathbf{V}_{bn} = V_p \angle -120°, \qquad \mathbf{V}_{cn} = V_p \angle +120°$$

12.11-rasm. Muvozanatlangan Y-Y shaklida ulanish.

Tarmoq kuchlanish U_{ab}, U_{bc} va U_{ca} faza kuchlanishlari bilan bog‘liq.

$$\mathbf{V}_{ab} = \mathbf{V}_{an} + \mathbf{V}_{nb} = \mathbf{V}_{an} - \mathbf{V}_{bn} = V_p\angle 0° - V_p\angle -120°$$

$$= V_p\left(1 + \frac{1}{2} + j\frac{\sqrt{3}}{2}\right) = \sqrt{3}V_p\angle 30°$$

$$\mathbf{V}_{bc} = \mathbf{V}_{bn} - \mathbf{V}_{cn} = \sqrt{3}V_p\angle -90°$$

$$\mathbf{V}_{ca} = \mathbf{V}_{cn} - \mathbf{V}_{an} = \sqrt{3}V_p\angle -210°$$

Shunday qilib, tarmoq kuchlanishlarining kattaligi U_L faza kuchlanishi U_p ning qiymatidan $\sqrt{3}$ barobar kattadir.

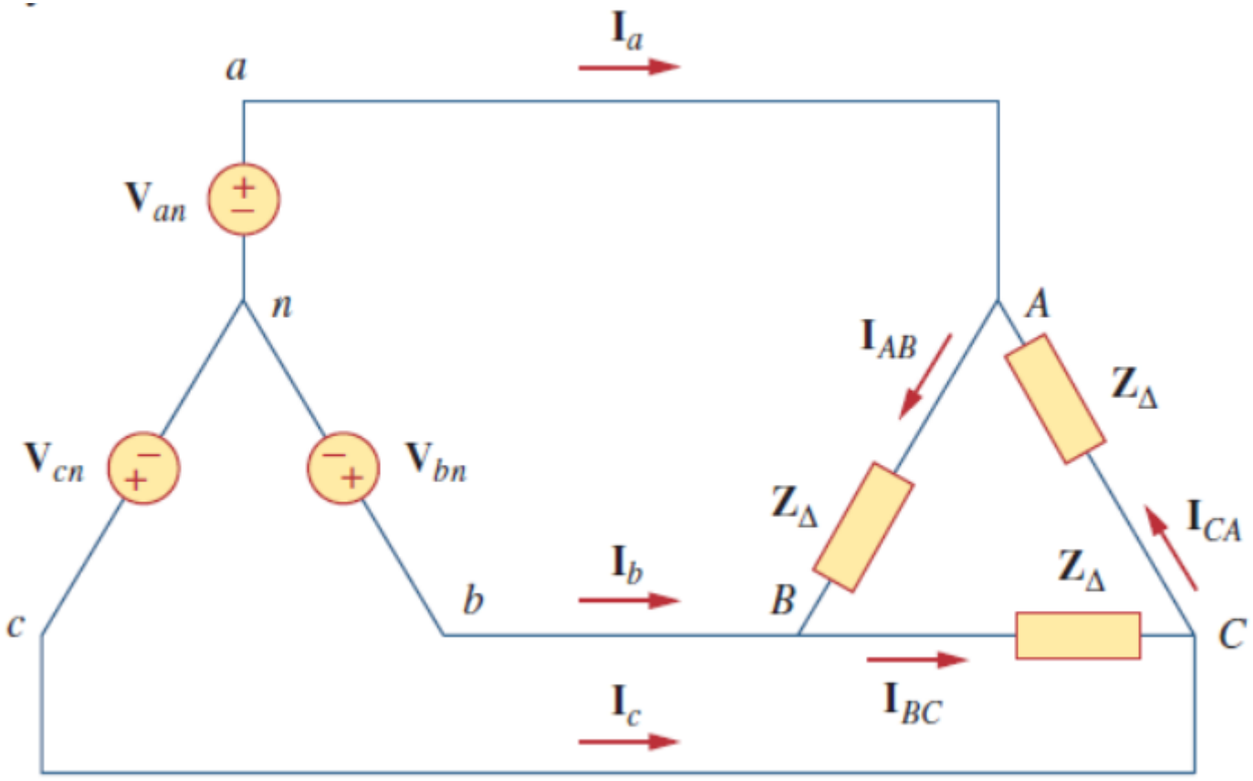
$$V_L = \sqrt{3}V_p$$

$$V_L = |\mathbf{V}_{ab}| = |\mathbf{V}_{bc}| = |\mathbf{V}_{ca}| \qquad V_p = |\mathbf{V}_{an}| = |\mathbf{V}_{bn}| = |\mathbf{V}_{cn}|$$

Bundan tashqari, tarmoq kuchlanishlari mos keladigan faza kuchlanishlaridan 30° ga ilgarilaydi.

12.4. Muvozanatlangan yulduz-uchburchak shakldagi (Y-Δ) ulanish.

Muvozanatlangan yulduz-uchburchak tizimi muvozanatli uchburchak shaklida ulangan yuklamani ta’minlaydigan muvozanatli yulduz shaklida ulangan manbadan iborat.



Muvozanatlangan yulduz-uchburchak tizimi 12.12-rasmda ko‘rsatilgan.

Bu yerda manba “yulduz” sxemasiga muvofiq, yuklama esa “uchburchak” sxema bo‘yicha ulanadi.

Albatta, bu holda manbadan yuklamaga neytral aloqa yo‘q.

12.12-rasm. Muvozanatlangan Y-Δ shaklida ulanish.

Ijobiy ketma-ketlikni hisobga olib, faza kuchlanishlari:

$$\mathbf{V}_{an} = V_p \angle 0°$$

$$\mathbf{V}_{bn} = V_p \angle -120°, \qquad \mathbf{V}_{cn} = V_p \angle +120°$$

Tarmoq kuchlanishlari:

$$\mathbf{V}_{ab} = \sqrt{3} V_p \angle 30° = \mathbf{V}_{AB}, \qquad \mathbf{V}_{bc} = \sqrt{3} V_p \angle -90° = \mathbf{V}_{BC}$$

$$\mathbf{V}_{ca} = \sqrt{3} V_p \angle -150° = \mathbf{V}_{CA}$$

Tarmoq kuchlanishlari ushbu tizim konfiguratsiyasi uchun yuklama impidenslaridagi kuchlanishlarga teng ekanligini ko‘rsatadi. Ushbu kuchlanishlardan biz fazali toklarni olishimiz mumkin. Ya’ni,

$$\mathbf{I}_{AB} = \frac{\mathbf{V}_{AB}}{\mathbf{Z}_\Delta}, \qquad \mathbf{I}_{BC} = \frac{\mathbf{V}_{BC}}{\mathbf{Z}_\Delta}, \qquad \mathbf{I}_{CA} = \frac{\mathbf{V}_{CA}}{\mathbf{Z}_\Delta}$$

Bu toklar bir xil kattalikka ega, lekin bir-biridan 120° fazadan farqlanadi.

Tarmoq toklari A, B va C tugunlarida KCLni qo‘llash orqali faza toklardan olinadi.

$$\mathbf{I}_a = \mathbf{I}_{AB} - \mathbf{I}_{CA}, \qquad \mathbf{I}_b = \mathbf{I}_{BC} - \mathbf{I}_{AB}, \qquad \mathbf{I}_c = \mathbf{I}_{CA} - \mathbf{I}_{BC}$$

Shuning bilan $\mathbf{I}_{CA} = \mathbf{I}_{AB}\angle -240°$,

$$\mathbf{I}_a = \mathbf{I}_{AB} - \mathbf{I}_{CA} = \mathbf{I}_{AB}(1 - 1\angle -240°)$$
$$= \mathbf{I}_{AB}(1 + 0.5 - j0.866) = \mathbf{I}_{AB}\sqrt{3}\angle -30°$$

Shunday qilib, tarmoq toklarining kattaligi I_L faza toki I_p ning qiymatidan $\sqrt{3}$ barobar kattadir.

$$I_L = \sqrt{3} I_p$$

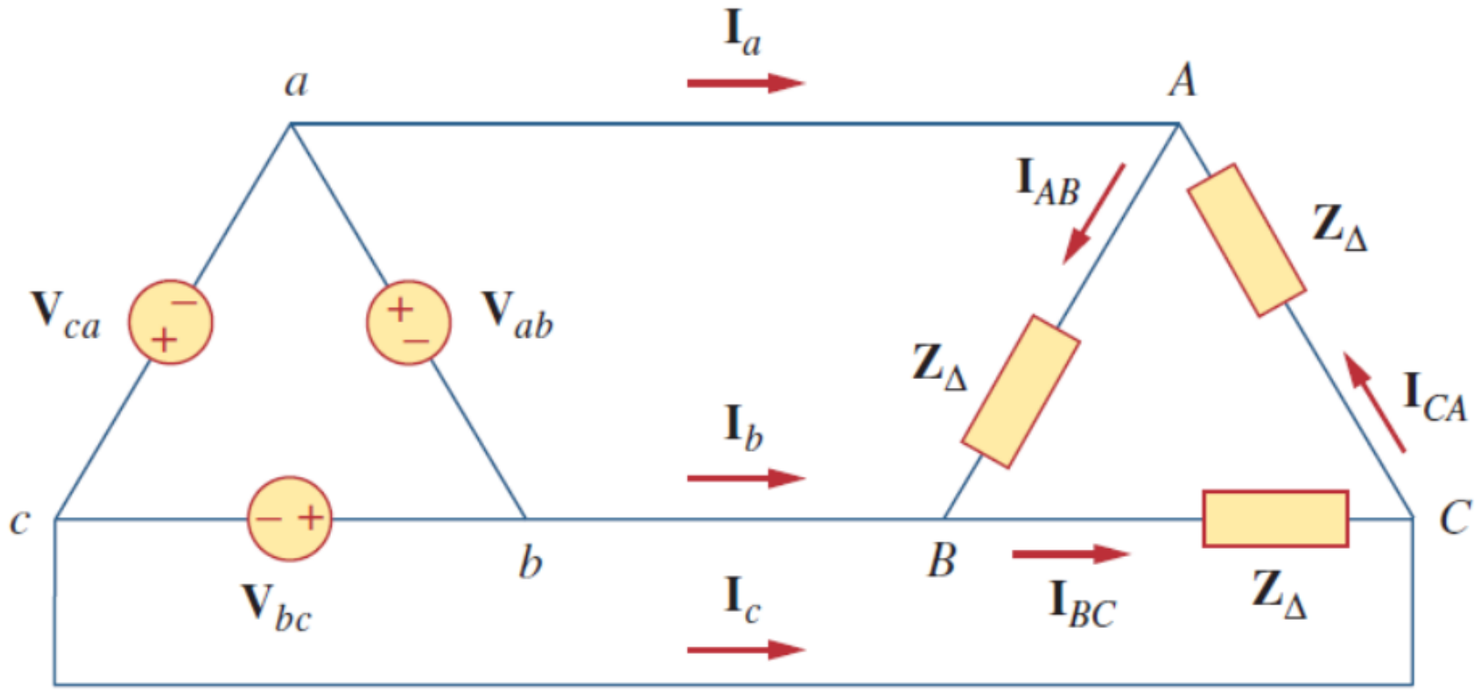
$$I_L = |\mathbf{I}_a| = |\mathbf{I}_b| = |\mathbf{I}_c| \qquad I_p = |\mathbf{I}_{AB}| = |\mathbf{I}_{BC}| = |\mathbf{I}_{CA}|$$

$$\mathbf{Z}_Y = \frac{\mathbf{Z}_\Delta}{3}$$

Bundan tashqari, tarmoq toklar mos keladigan faza toklaridan 30° ga kechikadi.

12.5. Muvozanatlangan uchburchak-uchburchak shakldagi (Δ-Δ) ulanish.

Muvozanatlangan uchburcha-uchburchak tizimi - bu muvozanatlangan har ikkala manba va yuklamalar uchburchak shaklida ulangan bo‘ladi.



12.13-rasm. Muvozanatlangan Δ -Δ shaklda ulanish.

Ijobiy ketma-ketlikni nazarda tutsak, uchburchak shaklida ulangan manba uchun faza kuchlanishlari:

$$\mathbf{V}_{ab} = V_p \angle 0°$$

$$\mathbf{V}_{bc} = V_p \angle -120°, \qquad \mathbf{V}_{ca} = V_p \angle +120°$$

Tarmoq kuchlanishlari faza kuchlanishlari bilan bir xil. 12.13-rasmdan tarmoq impidenslar yo‘q deb hisoblasak, uchburchak shaklida ulangan manbaning fazali kuchlanishlari impidenslardagi kuchlanishlarga teng.

$$\mathbf{V}_{ab} = \mathbf{V}_{AB}, \qquad \mathbf{V}_{bc} = \mathbf{V}_{BC}, \qquad \mathbf{V}_{ca} = \mathbf{V}_{CA}$$

Demak, faza toklari

$$\mathbf{I}_{AB} = \frac{\mathbf{V}_{AB}}{Z_\Delta} = \frac{\mathbf{V}_{ab}}{Z_\Delta}, \qquad \mathbf{I}_{BC} = \frac{\mathbf{V}_{BC}}{Z_\Delta} = \frac{\mathbf{V}_{bc}}{Z_\Delta}$$

$$\mathbf{I}_{CA} = \frac{\mathbf{V}_{CA}}{Z_\Delta} = \frac{\mathbf{V}_{ca}}{Z_\Delta}$$

Yuklama uchburchak shaklida ulanganligi sababli, u yerda olingan ba’zi ifodalar bu yerda qo‘llaniladi.

Tarmoq toklari A, B va C tugunlarida KCLni qo‘llash orqali faza toklaridan olinadi:

$$\mathbf{I}_a = \mathbf{I}_{AB} - \mathbf{I}_{CA}, \qquad \mathbf{I}_b = \mathbf{I}_{BC} - \mathbf{I}_{AB}, \qquad \mathbf{I}_c = \mathbf{I}_{CA} - \mathbf{I}_{BC}$$

Har bir tarmoq toki mos keladigan faza tokidan 30° ga orqada qoladi.

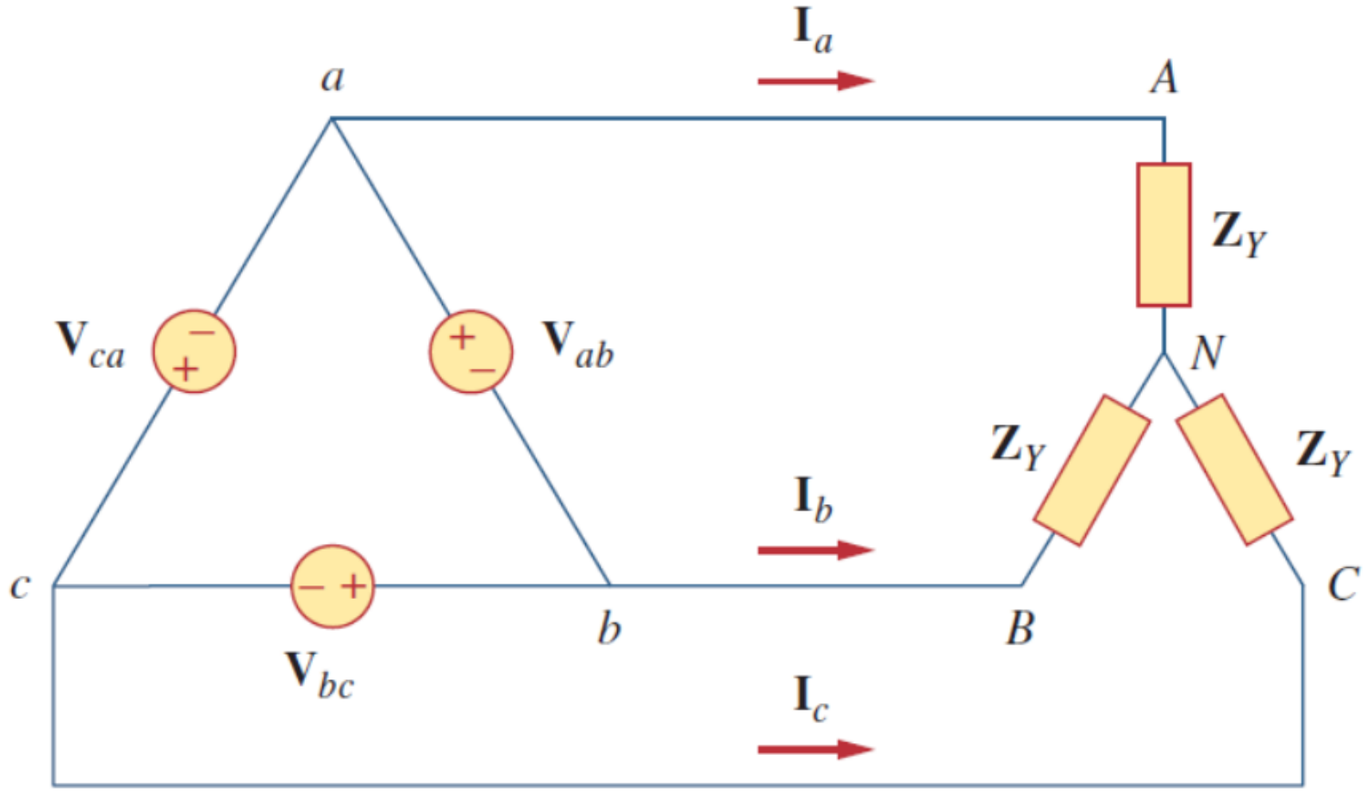
Tarmoq tokining kattaligi I_L faza toki I_p ning qiymatidan $\sqrt{3}$ barobar kattadir.

$$I_L = \sqrt{3} I_p$$

Δ-Δ shaklida sxemani tahlil qilishning muqobil usuli ham manbani, ham yuklamani ularning Y ekvivalentlariga aylantirishdan iborat.

12.6. Muvozanatlangan uchburchak-yulduz shakldagi (Δ-Y) ulanish.

Muvozanatlangan uchburchak-yulduz tizimi – bu muvozanatli yulduz shaklida ulangan yuklamani ta’minlovchi muvozanatli uchnurchak shaklida ulangan manbadan iborat.



12.14-rasm. Muvozanatlangan Δ -Y shaklda ulanish.

abc ketma-ketligini hisobga olsak, uchburchak bilan bog‘langan manbaning fazali kuchlanishlari:

$$\mathbf{V}_{ab} = V_p\angle 0^\circ, \qquad \mathbf{V}_{bc} = V_p\angle -120^\circ$$
$$\mathbf{V}_{ca} = V_p\angle +120^\circ$$

Shuningdek, tarmoq (liniya) kuchlanishlari faza kuchlanishlari bilan bir xil.

Tarmoq toklarini ko‘p usullar bilan olishimiz mumkin.

aANBba kontur uchun KVL ni qo‘llaymiz.

$$-\mathbf{V}_{ab} + \mathbf{Z}_Y\mathbf{I}_a - \mathbf{Z}_Y\mathbf{I}_b = 0 \quad \text{yoki,} \quad \mathbf{Z}_Y(\mathbf{I}_a - \mathbf{I}_b) = \mathbf{V}_{ab} = V_p\angle 0°$$

Demak, $$\mathbf{I}_a - \mathbf{I}_b = \frac{V_p\angle 0°}{\mathbf{Z}_Y}$$

Lekin I_b I_a dan 120° ga orqada qoladi, chunki *abc* ketma-ketlida deb hisobga qildik.

Ya’ni $I_b = I_a\angle -120°$. Demak,

$$\mathbf{I}_a - \mathbf{I}_b = \mathbf{I}_a(1 - 1\angle -120°)$$

$$= \mathbf{I}_a\left(1 + \frac{1}{2} + j\frac{\sqrt{3}}{2}\right) = \mathbf{I}_a\sqrt{3}\angle 30°$$

$$\mathbf{I}_a = \frac{V_p/\sqrt{3}\angle -30°}{\mathbf{Z}_Y}$$

Bu yerdan biz to‘g‘ridan-to‘g‘ri fazalar ketma-ketligidan foydalanib, I_b va I_c gachasi boshqa tarmoq toklarini olamiz, ya’ni $I_b = I_a\angle -120°$, $I_c = I_a\angle +120°$.

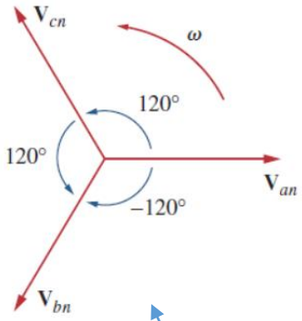
Faza toklari tarmoq toklariga teng.

Uchburchak shaklida ulangan manbani uning ekvivalent yulduz shaklida ulangan manba bilan almashtirish mumkin.

Shuning uchun, biz uchburchak shaklida ulangan manbaning mos keladigan tarmoqli kuchlanishini $\sqrt{3}$ ga bo‘lish va uning fazasini -30° ga almashtirish orqali ekvivalent Y bog‘langan manbaning har bir fazali kuchlanishini olamiz.

Muvozanatlangan uch fazali tizimlar uchun faza va tarmoq kuchlanish / toklarining qisqacha mazmuni*.

Connection	Phase voltages/currents	Line voltages/currents
Y-Y	$\mathbf{V}_{an} = V_p\angle 0°$ $\mathbf{V}_{bn} = V_p\angle -120°$ $\mathbf{V}_{cn} = V_p\angle +120°$ Same as line currents	$\mathbf{V}_{ab} = \sqrt{3}V_p\angle 30°$ $\mathbf{V}_{bc} = \mathbf{V}_{ab}\angle -120°$ $\mathbf{V}_{ca} = \mathbf{V}_{ab}\angle +120°$ $\mathbf{I}_a = \mathbf{V}_{an}/\mathbf{Z}_Y$ $\mathbf{I}_b = \mathbf{I}_a\angle -120°$ $\mathbf{I}_c = \mathbf{I}_a\angle +120°$
Y-Δ	$\mathbf{V}_{an} = V_p\angle 0°$ $\mathbf{V}_{bn} = V_p\angle -120°$ $\mathbf{V}_{cn} = V_p\angle +120°$ $\mathbf{I}_{AB} = \mathbf{V}_{AB}/\mathbf{Z}_\Delta$ $\mathbf{I}_{BC} = \mathbf{V}_{BC}/\mathbf{Z}_\Delta$ $\mathbf{I}_{CA} = \mathbf{V}_{CA}/\mathbf{Z}_\Delta$	$\mathbf{V}_{ab} = \mathbf{V}_{AB} = \sqrt{3}V_p\angle 30°$ $\mathbf{V}_{bc} = \mathbf{V}_{BC} = \mathbf{V}_{ab}\angle -120°$ $\mathbf{V}_{ca} = \mathbf{V}_{CA} = \mathbf{V}_{ab}\angle +120°$ $\mathbf{I}_a = \mathbf{I}_{AB}\sqrt{3}\angle -30°$ $\mathbf{I}_b = \mathbf{I}_a\angle -120°$ $\mathbf{I}_c = \mathbf{I}_a\angle +120°$
Δ-Δ	$\mathbf{V}_{ab} = V_p\angle 0°$ $\mathbf{V}_{bc} = V_p\angle -120°$ $\mathbf{V}_{ca} = V_p\angle +120°$ $\mathbf{I}_{AB} = \mathbf{V}_{ab}/\mathbf{Z}_\Delta$ $\mathbf{I}_{BC} = \mathbf{V}_{bc}/\mathbf{Z}_\Delta$ $\mathbf{I}_{CA} = \mathbf{V}_{ca}/\mathbf{Z}_\Delta$	Same as phase voltages $\mathbf{I}_a = \mathbf{I}_{AB}\sqrt{3}\angle -30°$ $\mathbf{I}_b = \mathbf{I}_a\angle -120°$ $\mathbf{I}_c = \mathbf{I}_a\angle +120°$
Δ-Y	$\mathbf{V}_{ab} = V_p\angle 0°$ $\mathbf{V}_{bc} = V_p\angle -120°$ $\mathbf{V}_{ca} = V_p\angle +120°$ Same as line currents	Same as phase voltages $\mathbf{I}_a = \dfrac{V_p\angle -30°}{\sqrt{3}\mathbf{Z}_Y}$ $\mathbf{I}_b = \mathbf{I}_a\angle -120°$ $\mathbf{I}_c = \mathbf{I}_a\angle +120°$



*Ijobiy yoki ***abc*** ketma-ketligi qabul qilinadi.

Shunday qilib, ekvivalent Y-ulangan manba fazali kuchlanishlarga ega:

$$\mathbf{V}_{an} = \frac{V_p}{\sqrt{3}}\angle -30°$$

$$\mathbf{V}_{bn} = \frac{V_p}{\sqrt{3}}\angle -150°, \qquad \mathbf{V}_{cn} = \frac{V_p}{\sqrt{3}}\angle +90°$$

Photo source: [17] - Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 518.

FOYDALANILGAN MANBALAR:

1. https://i.ytimg.com/vi/NdEqUfUiCBU/sddefault.jpg
2. https://i.ytimg.com/vi/84-oxotGYGM/hqdefault.jpg
3. https://i.ytimg.com/vi/4anR5Zcsx0Y/sddefault.jpg
4. https://i.ytimg.com/vi/XMpJuIIzM1M/hqdefault.jpg
5. https://i.ytimg.com/vi/nd-O1ifRhpI/hqdefault.jpg
6. https://upload.wikimedia.org/wikipedia/commons/thumb/4/48/3-phase_flow.gif/357px-3-phase_flow.gif
7. Fundamentals of Electric Circuits, Charles K. Alexander and Matthew N. O. Sadiku / 5th edition, the McGraw-Hill Companies, Inc., -2013. – p 518.

TEKSHIRISH UCHUN SAVOLLAR!

12.1. $U_{AN} = 220\angle -100°\, V$ va $U_{BN} = 220\angle 140°\, V$ bo‘lgan uch fazali dvigatelning fazalar ketma-ketligi qanday?
A) abc. B) acb.

12.2. Agar *acb* fazalar ketma-ketligida $U_{an} = 100\angle -20°$ bo‘lsa, u holda U_{cn}:
A) $100\angle -140°$. B) $100\angle 100°$.
C) $100\angle -50°$. D) $100\angle 10°$.

12.3. Ulardan qaysi biri muvozanatli tizim uchun shart emas:
A) $|U_{an}| = |U_{bn}| = |U_{cn}|$.
B) $I_a + I_b + I_c = 0$.
C) $U_{an} + U_{bn} + U_{cn} = 0$.
D) manba kuchlanishlari bir-biri bilan fazadan tashqarida.
E) uch faza uchun yuklama impidenslari teng.

12.4. Y-ulangan yuklamada tarmoq toki va faza toki tengdir.
A) To‘g‘ri. B) Noto‘g‘ri.

12.5. Δ-ulangan yuklamada tarmoq toki va faza toki tengdir.
A) To‘g‘ri. B) Noto‘g‘ri.

12.6. Y-Y tizimida 220 V liniyadagi kuchlanish quyidagi faza kuchlanishini hosil qiladi:
A) 381 V. B) 311 V.
C) 220 V. D) 156 V. E) 127 V

12.7. Δ-Δ tizimida 100 V liniyadagi kuchlanish quyidagi faza kuchlanishini hosil qiladi:
A) 58 V. B) 71 V.
C) 100 V. D) 173 V. E) 141 V

12.8. Y-ulangan yuklama *abc* fazalar ketma-ketligidagi kuchlanishlar bilan ta’minlanganda, liniya kuchlanishlari mos keladigan faza kuchlanishlaridan ortda qoladi.
A) To‘g‘ri. B) Noto‘g‘ri.

12.9. Muvozanatlangan uch fazali sxemada jami oniy quvvat o‘rtacha quvvatga teng.
A) To‘g‘ri. B) Noto‘g‘ri.

12.10. Muvozanatlangan yuklamaga beriladigan umumiy quvvat muvozanatli Y-yuklama bilan bir xil tarzda topiladi.
A) To‘g‘ri. B) Noto‘g‘ri.

E'TIBORINGIZ UCHUN RAHMAT!!!