12-Mavzu: Uch fazali zanjirlar.

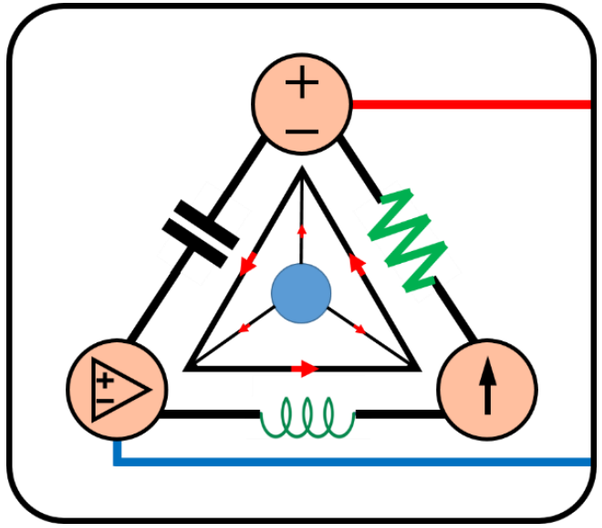
(12th Topic: Three-Phase Circuits.)

12-Mavzuning 1-qismi

(1st part of the 12th Topic)

15-hafta uchun

For the 15th week



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Toshkent shahri, Usmon Nosir, 156-uy.

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.

12.1. Umumiy tushunchalar

Elektr energiyasini bir turdan boshqa turga aylantirishning barcha fizikaviy jarayonlarini amalga oshirishda hozirgi zamon elektrotexnikasi barcha sohalarining asosini tashkil etadi.

EYuK, kuchlanish, tok va elektromagnitli miqdorlarning vaqt bo‘yicha o‘zgarishi bilan bog‘liq bo‘ladi.

O‘zgaruvchan tok vaqt bo‘yicha va ma’lum qonun bo‘yicha o‘zgaradi, ya’ni tokning miqdori vaqtning funksiyasidir.

Shunday qilib, vaqt o‘tishi bilan miqdori va yo‘nalishi o‘zgaradigan tokga o‘zgaruvchan tok deb aytiladi.

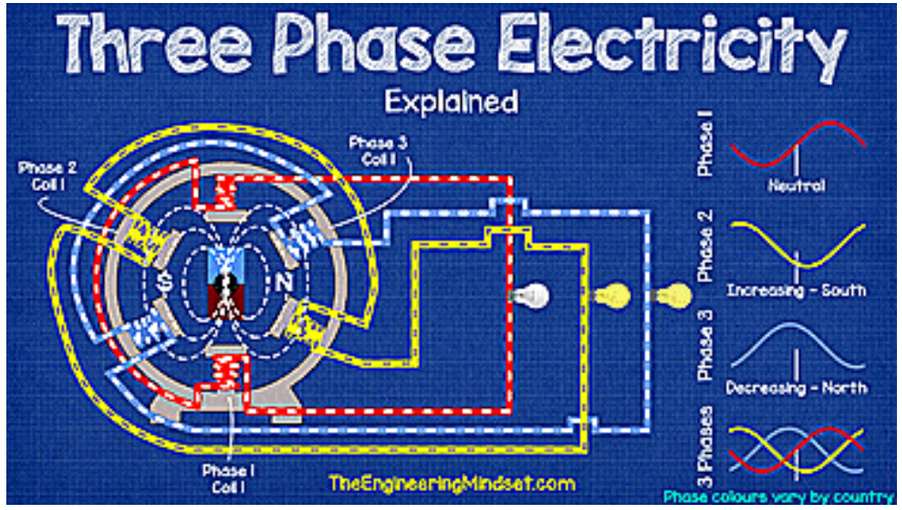
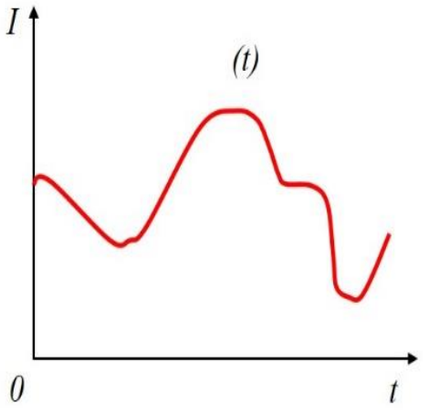
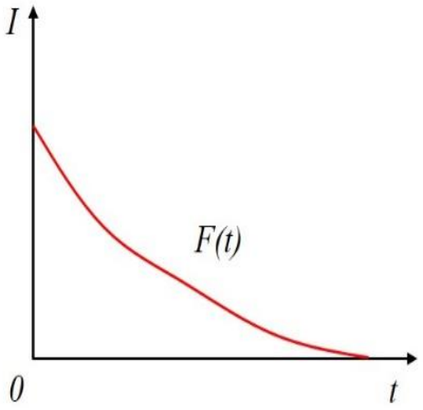


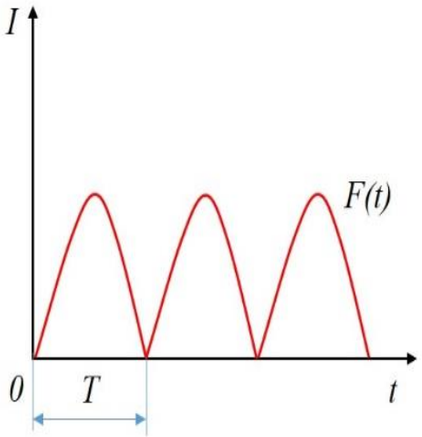
Photo source: [1] - https://theengineeringmindset.com/wp-content/uploads/2018/02/three-phase-ac-generator.gif

O‘zgaruvchan tokni uch turga bo‘lish mumkin:

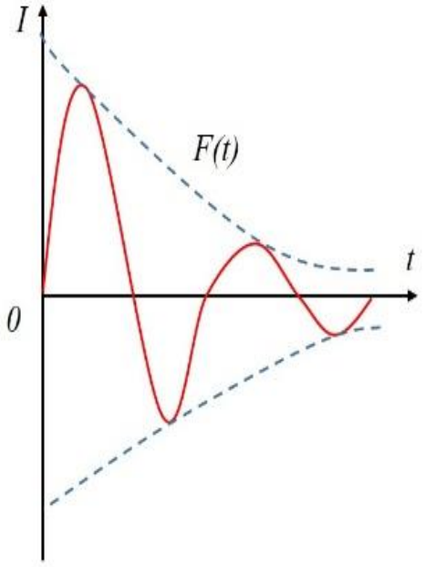
1. Miqdori o‘zgaruvchan, ammo yo‘nalishi o‘zgarmas (pulsatsiyalanuchi) tok (12.1- rasmlar *a*, *b*, *c*).

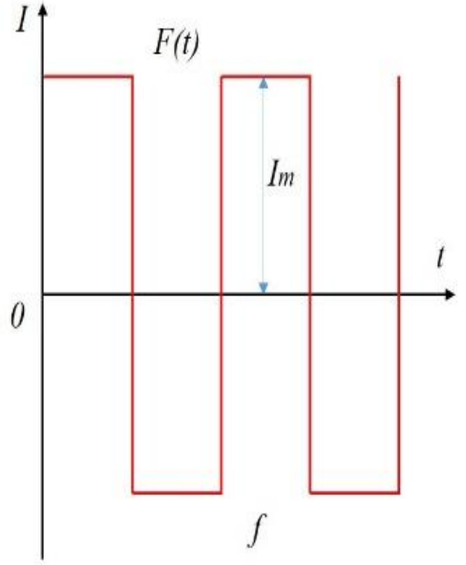




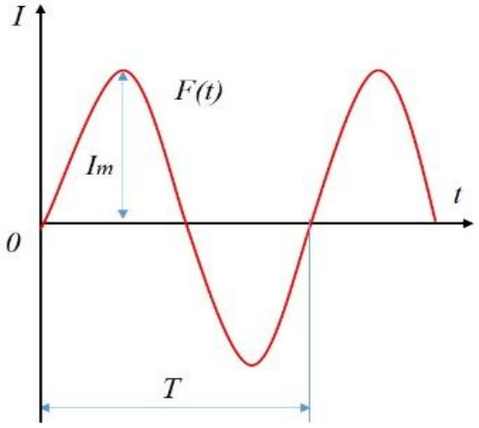


2. Miqdori va yo‘nalishi o‘zgaruvchan tok (12.1-rasmlar *d*, *e*).



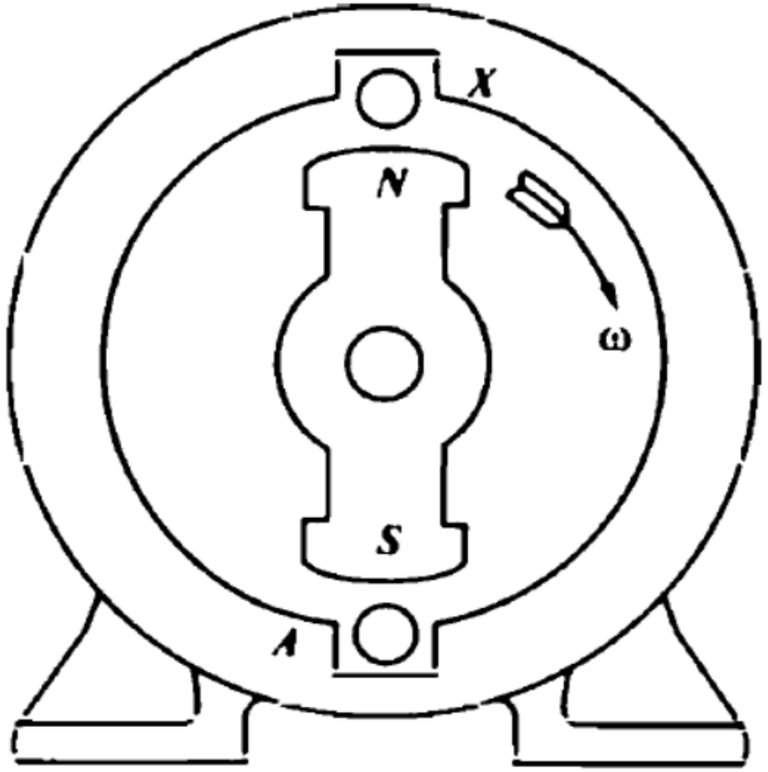


3. Davriy o‘zgaruvchan tok (12.1-rasm, *f*).



12.1-rasm.

O‘zgaruvchan tokning eng ko‘p tarqalgan manbalaridan biri mexanikaviy energiyani elektr energiyasiga aylantirib beruvchi sinxron generatordir.



12.2-rasm. Ikki qutbli generator.

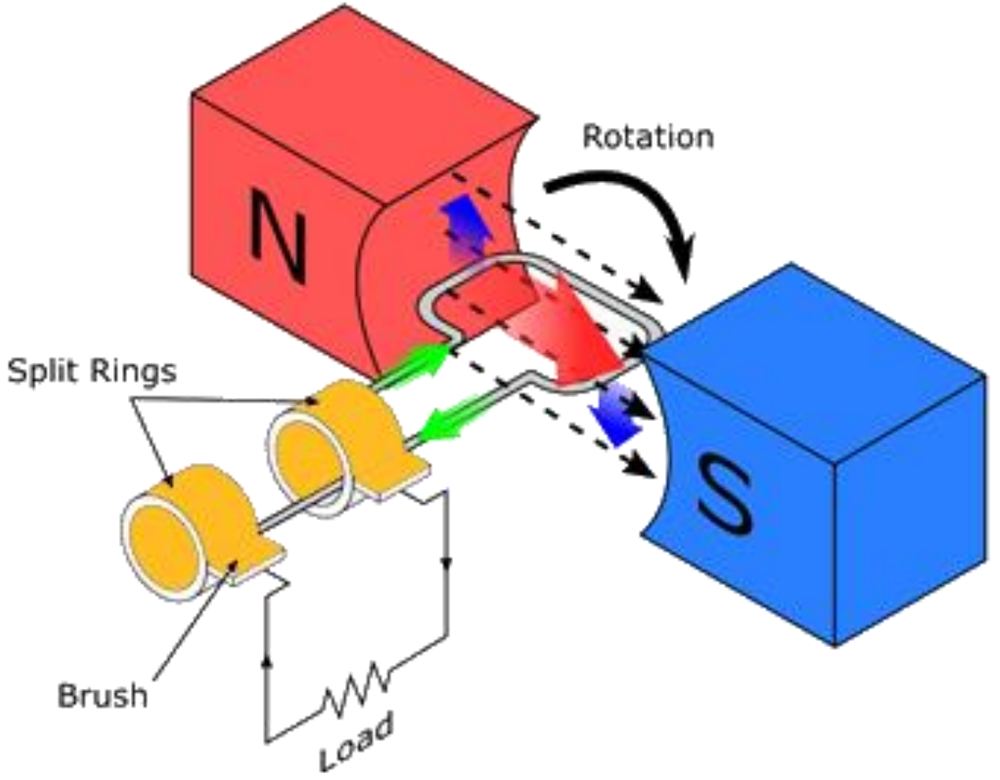


Photo source: [2] - https://savree-storage.s3.amazonaws.com/Articles/optimised/3.7.1-Simple-AC-Generator.png

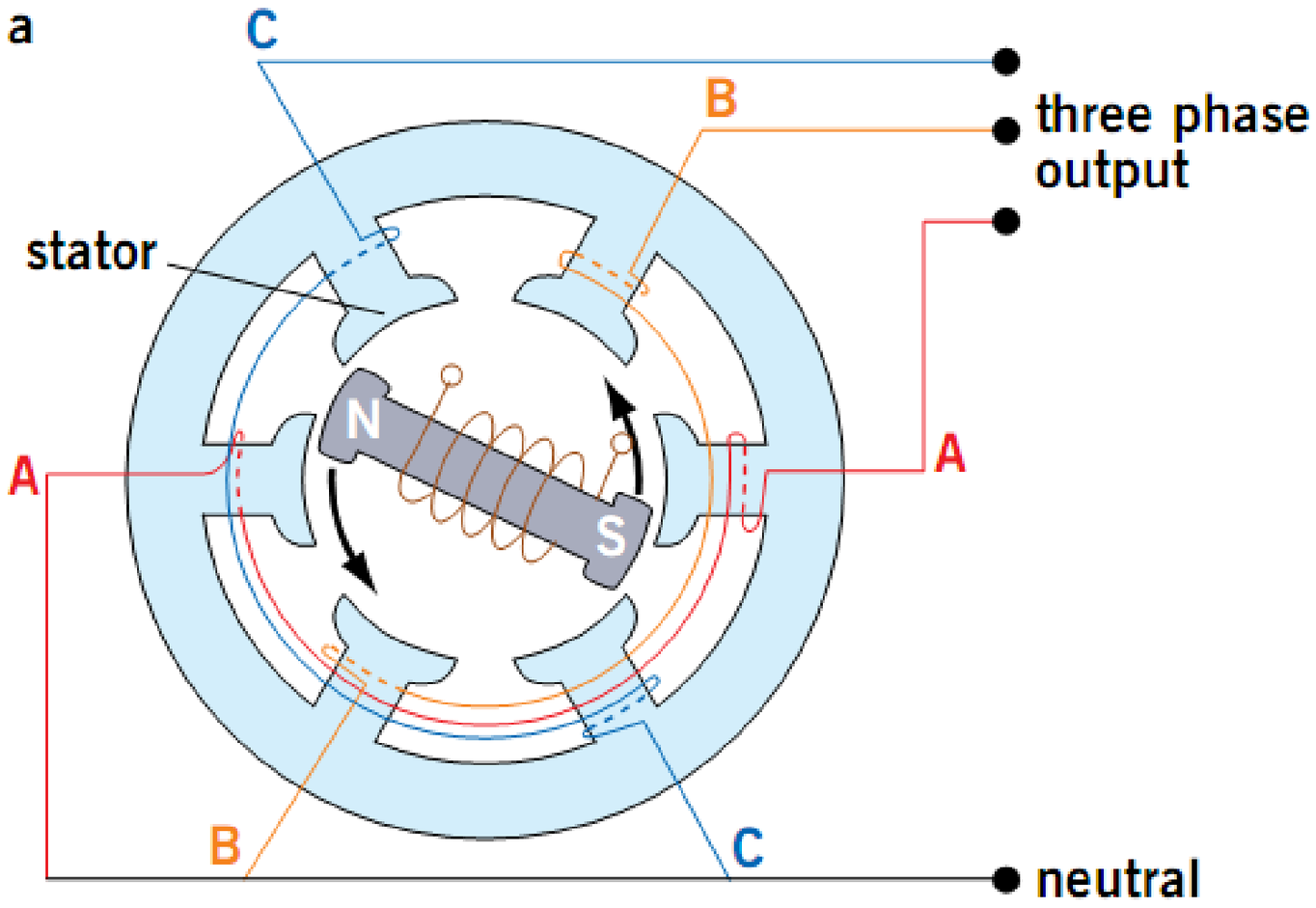


Photo source: [3] - https://d3jlfsfsyc6yvi.cloudfront.net/image/mw:1024/q:85/https%3A%2F%2Fhaygot.s3.amazonaws.com%3A443%2Fcheatsheet%2F21515.png

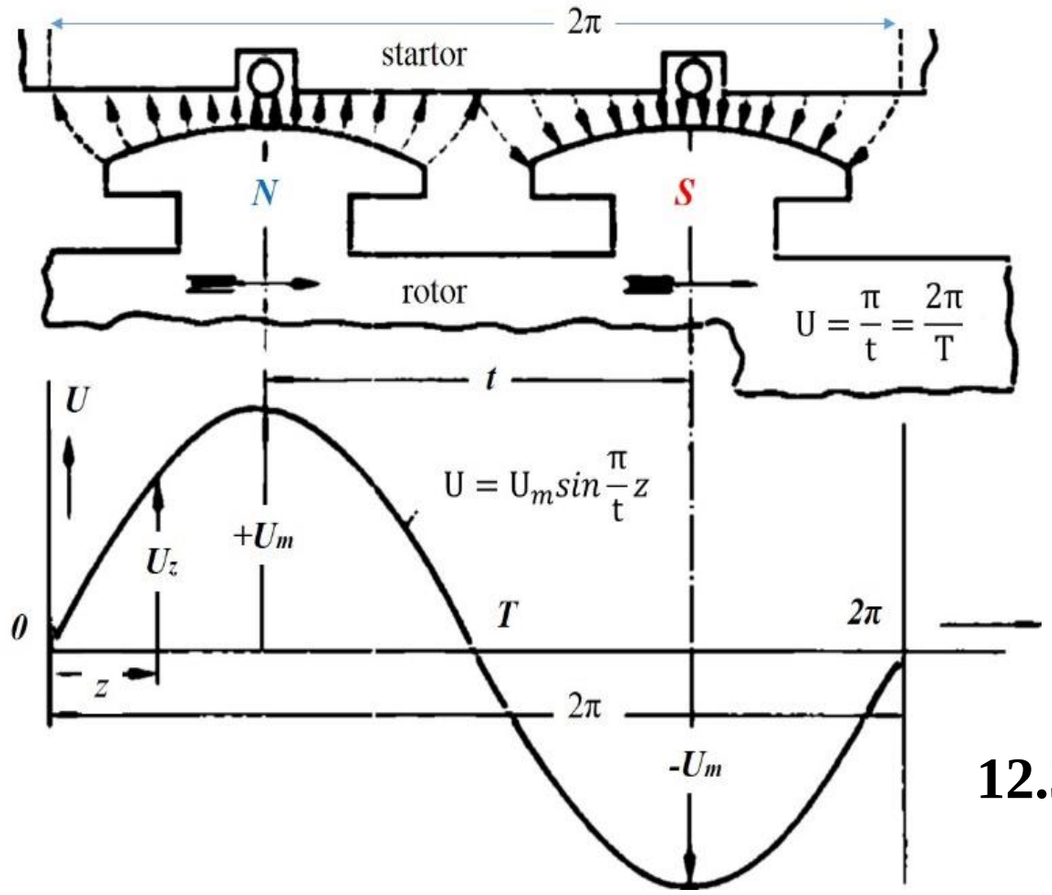
Generatorning qo‘zg‘almas qismini stator deyiladi.

Harakatlanuvchi o‘zgarmas magnitli qismini rotor deb ataladi.

Statorda chuqur ariqchalarga o‘rnatilgan o‘ramlar bo‘lib, ularning uchlaridan o‘tkazgichlar (simlar orqali) elektr toki iste’molchilarga uzatiladi.

Generatorning magnitli rotori mexanikaviy kuch bilan aylantirilganda, generatorning o‘ramlarida elektr hosil bo‘ladi.

$$f = \frac{P \cdot n}{60}\ (Hz) \qquad (12.1)$$



Magnitli rotor aylanganida qo‘zg‘almas statordagi izolyatsiyali o‘tkazgichlarni magnit maydonini kesib o‘tadi, mashinada o‘zgaruvchan tok hosil bo‘ladi.

12.3-rasm. Stator bilan rotor oralig‘idagi magnit induksiyasining taqsimlanish egri chizig‘i.

Bunday elektr mashinani bir fazali o‘zgaruvchan tok generatori deyiladi. O‘zgaruvchan tok manbalari har xil bo‘lishi mumkin.

O‘zgaruvchan tok generatorining rotoriga o‘tkazgich o‘ramlari joylashtirilgan bo‘lsa, u holda rotordagi o‘ramlarga o‘zgarmas elektr toki ulanib, unda elektr magnit hosil qilinadi.

Bu o‘ramlar o‘zgaruvchan tok generatorining qo‘zg‘atuvchan cho‘lg‘amlari deb ataladi.

Bunday generatorlarda miqdori va yo‘nalishi o‘zgaruvchan tok hosil bo‘ladi.

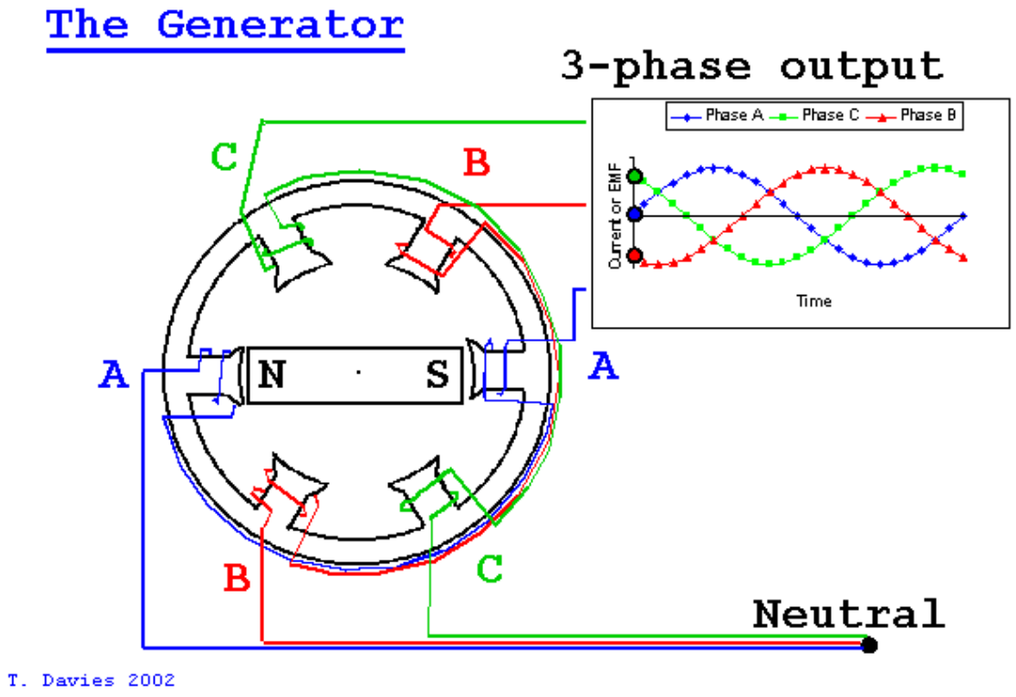
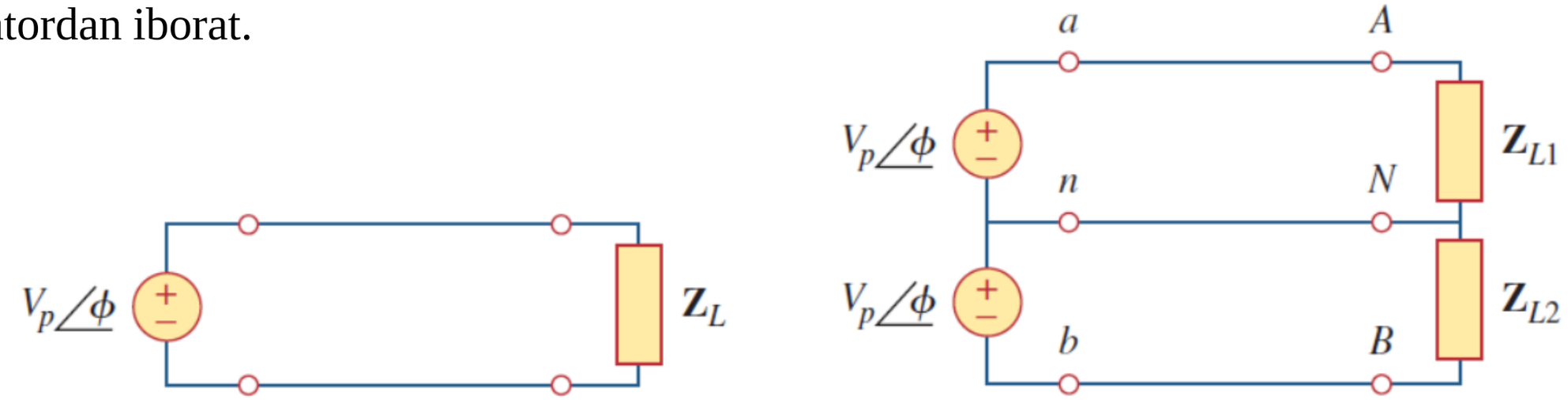


Photo source: [4] - https://i.stack.imgur.com/4TsG7.gif

Bir fazali o‘zgaruvchan quvvat tizimi bir juft sim (uzatish liniyasi) orqali yuklamaga ulangan generatordan iborat.



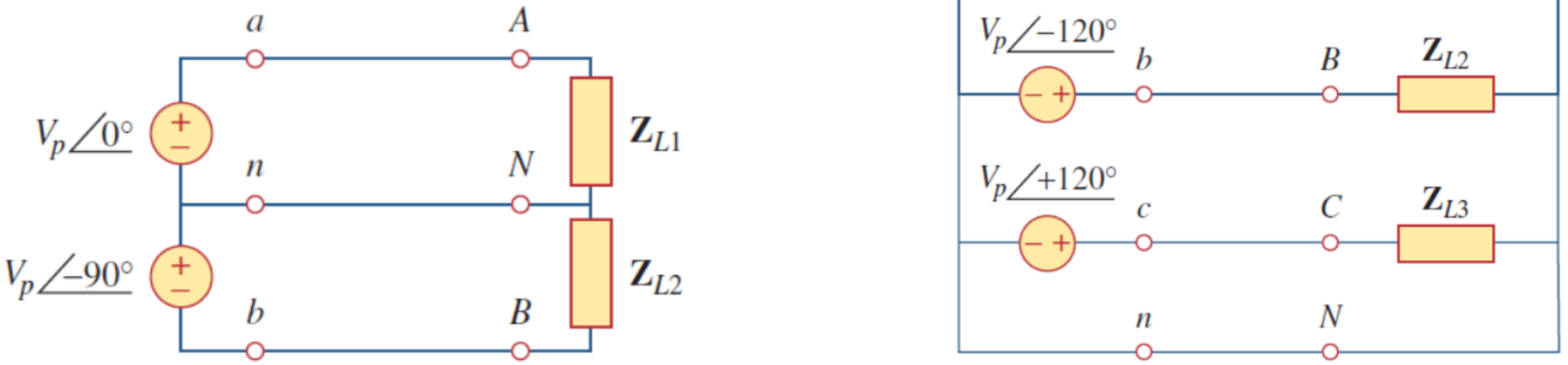
a) b)

12.4-rasm. Bir fazali tizimlar: a) ikki simli turi, b) uch simli turi.

Misol uchun uy xo‘jaligi tizimi bir fazali uch simli tizimdir, chunki terminal kuchlanishlari bir xil kattalik va bir xil fazaga ega. 120 V, 240 V qurilmalarni ulash imkonini beradi.

Bu yerda: U_p - manba kuchlanishining *rms* kattaligi va ϕ burchsk fazasidir.

O‘zgaruvchan tok manbalari bir xil chastotada, lekin turli fazalarda ishlaydigan zanjirlar yoki tizimlar ko‘p fazali deb nomlanadi.



a) b)

12.5-rasm. a) ikki fazali uch o‘ramli tizim. b) uch fazali to‘rt o‘ramli tizim.

Uch fazali tizim hozirgacha eng keng tarqalgan va eng tejamkor ko‘p fazali tizim hisoblanadi.

Uch fazali tizimlar kamida uchta sababga ko‘ra muhimdir:

Birinchidan, dunyo bo‘yicha deyarli barcha elektr energiyalar 60 Hz (yoki $\omega=(2\pi f=2*3,14*60)=377\ rad/s$) yoki 50 Hz (yoki $\omega=314\ rad/s$) ish chastotasida uch fazali qilib ishlab chiqariladi va taqsimlanadi.

Bir fazali yoki ikki fazali toklar kerak bo‘lganda, ular mustaqil ravishda ishlab chiqarilgandan ko‘ra uch fazali tizimdan olinadi.

Hatto uchdan ortiq fazalar kerak bo‘lganda ham, masalan, alyuminiy sanoatida eritish uchun 48 faza kerak bo‘lsa ham, ular taqdim etilgan uchta fazani manipulyatsiya qilish orqali ta`minlanishi mumkin.

Photo source: [5] - https://www.sjcsal.com/wp-content/uploads/2022/02/app2.jpg

Ikkinchidan, uch fazali tizimdagi oniy quvvat doimiy bo‘lishi mumkin (pulsatsiyalanuvchi emas). Bu uch fazali mashinalarning bir xil quvvat uzatilishiga va kamroq tebranishiga olib keladi.

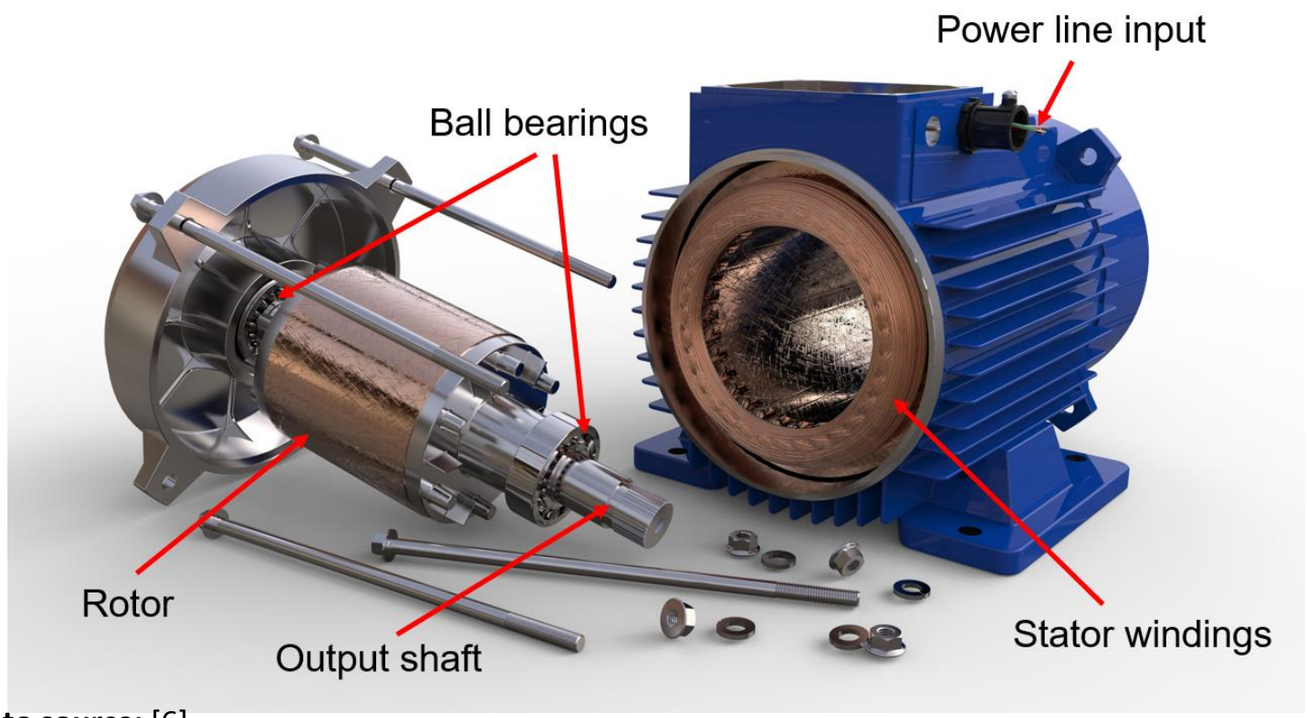


Photo source: [6] - https://www.keysight.com/blogs/tech/bench/2020/04/27/media_186a2819352658d56f73b4f9f34df7e5280b225a3.png?width=2000&format=webply&optimize=medium

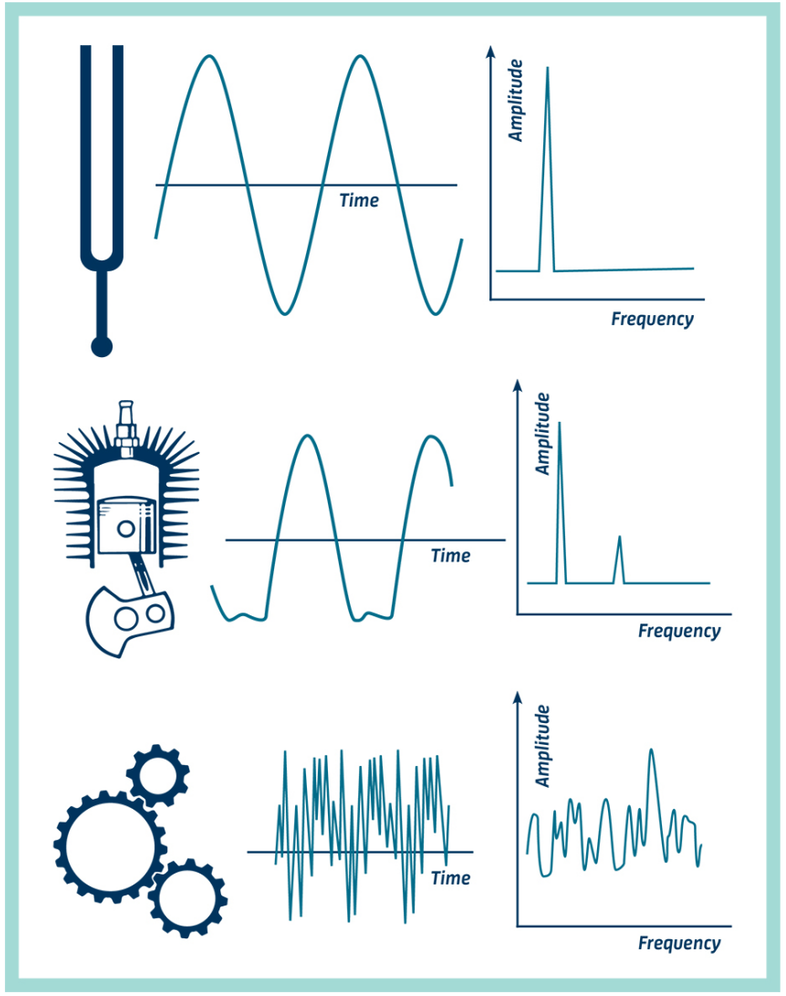


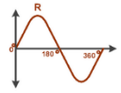
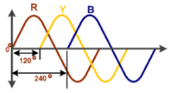
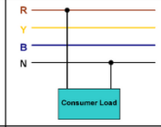
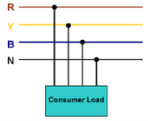
Photo source: [7] - https://www.envi.ro/wp-content/uploads/2021/10/vibration-measurement-768x980.webp

Uchinchidan, bir xil miqdordagi quvvat uchun uch fazali tizim bir fazaga qaraganda ancha tejamkor.

5. Three Phase A.C. Circuit

Darshan Institute of Engineering & Technology

5.1 Comparison between single phase and three phase

Basis for Comparison	Single Phase	Three Phase
Definition	The power supply through one conductor.	The power supply through three conductors.
Wave Shape		
Number of wire	Require two wires for completing the circuit	Requires four wires for completing the circuit
Voltage	Carry 230V	Carry 415V
Phase Name	Split phase	No other name
Network	Simple	Complicated
Loss	Maximum	Minimum
Power Supply Connection		
Efficiency	Less	High
Economical	Less	More
Uses	For home appliances.	In large industries and for running heavy loads.

5.2 Generation of three phase EMF

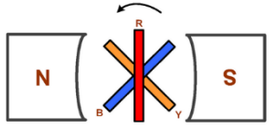
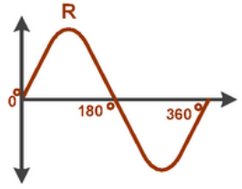
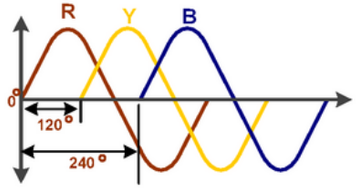
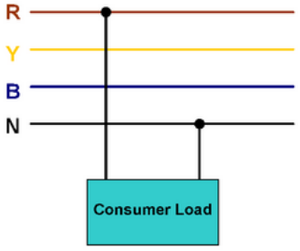
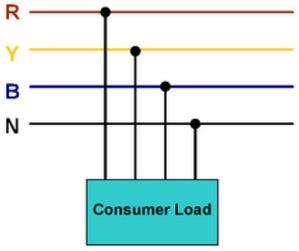


Figure 5.1 Generation of three phase emf

- According to Faraday's law of electromagnetic induction, we know that whenever a coil is rotated in a magnetic field, there is a sinusoidal emf induced in that coil.

Bhavesh M Jesadia, EE Department | Elements of Electrical Engineering (210005) | 1

Photo source: [8] - https://www.studocu.com/in/document/savitribai-phule-pune-university/basic-electrical-engineering/three-phase-circuit/7783247

Basis for Comparison	Single Phase	Three Phase
Definition	The power supply through one conductor.	The power supply through three conductors.
Wave Shape		
Number of wire	Require two wires for completing the circuit	Requires four wires for completing the circuit
Voltage	Carry 230V	Carry 415V
Phase Name	Split phase	No other name
Network	Simple	Complicated
Loss	Maximum	Minimum
Power Supply Connection		
Efficiency	Less	High
Economical	Less	More
Uses	For home appliances.	In large industries and for running heavy loads.

12.2. Muvozanatlangan uch fazali kuchlanishlar.

Uch fazali kuchlanish ko‘pincha uch fazali o‘zgaruvchan tok generatori bilan ishlab chiqariladi.

Uch fazali tokning eng ahamiyatli xossalaridan biri aylanuvchi magnit maydoni hosil qilishidir.

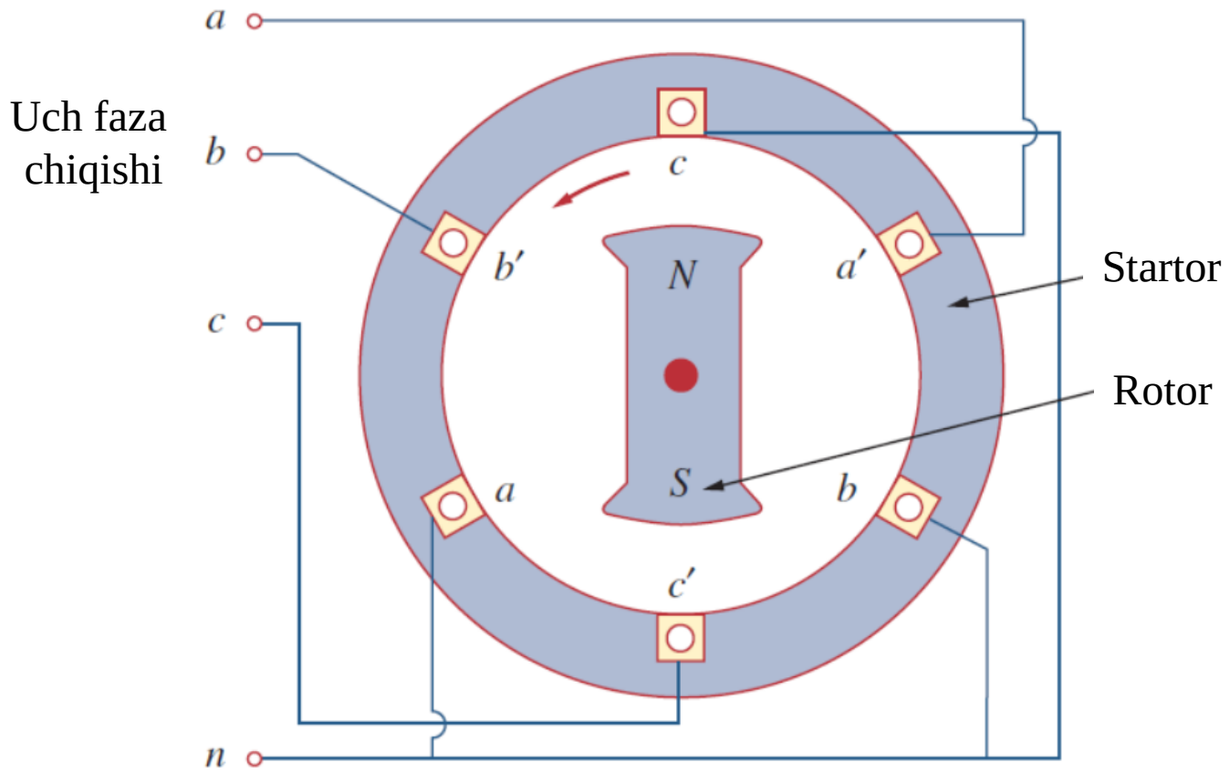
Generator asosan statsionar (qo‘zg‘almas) va aylanuvchi (qo‘zg‘aluvchi) qismlardan iborat.

Uning qo‘zg‘almas qismi stator deb, qo‘zg‘aluvchi qismi esa rotor deb ataladi.

Startor ichida o‘qlari bir-biriga nisbatan 120° burchak hosil qilib joylashtirilgan uchta induktiv chulg‘am joylashtiriladi.

Generatorning fazalarida chulg‘amlarini rotor bilan aylanayotgan o‘zgarmas magnit maydonini kesib o‘tishi natijasida E.Yu.K. hosil bo‘ladi.

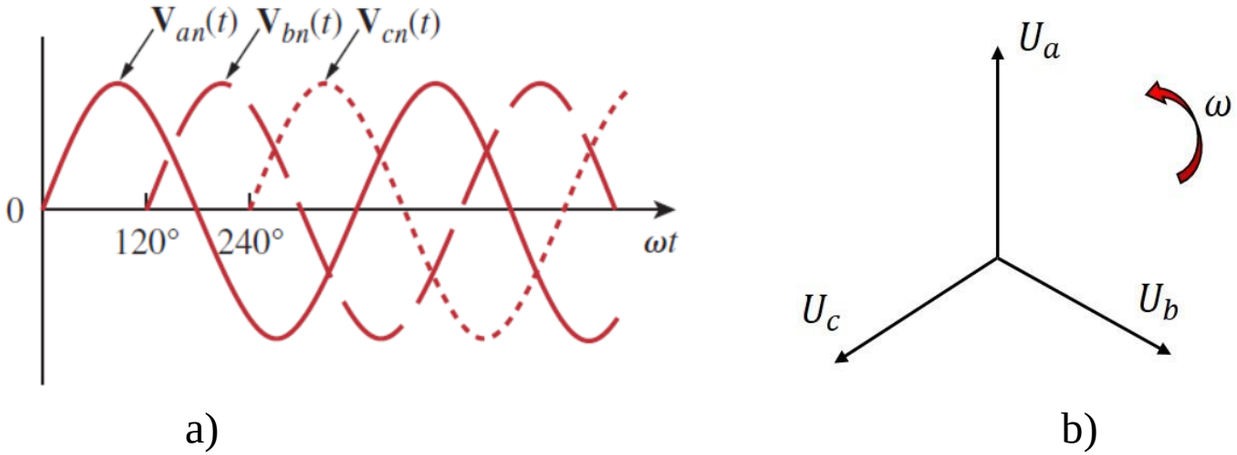
Rotorning chulg‘ami *a*-*a*`, *b*-*b*` va *c*-*c*` ikkita kontakt halqalar va grafit cho‘tka yordamida tashqi o‘zgarmas kuchlanish manbaiga ulanadi.



12.6-rasm. Uch fazali generator.

Chulg‘amlar yulduz shaklida ulanganda ularning oxiri *a*, *b*, *c* uchlarini bir-biriga ulab, neytral nuqta hosil qilinadi, chulg‘amlarning *a*`, *b*` va *c*` uchlari esa uch fazali tok tarmog‘iga ulanadi.

Bunday konstruksiyali generator har fazada elektromagnit miqdorining tebranishi bir xil chastota va amplituda bo‘lishini ta’minlaydi, chunki rotorning to‘la bir marta aylanishi ayrim fazalardagi E.Yu.K. to‘la cho‘qqi (piklik) (sinusoida qonuni bo‘yicha) o‘zgarishi bir davr T ga teng vaqtda sodir bo‘ladi.



a) b)

12.7-rasm. Ishlab chiqilgan kuchlanishlarning bir-biridan 120° ga farqlanishi.

a) uch fazali sistema E.Yu.K. ning oniy miqdorining o‘zgarishi;
b) uch fazali sistema E.Yu.K. ning vektori.

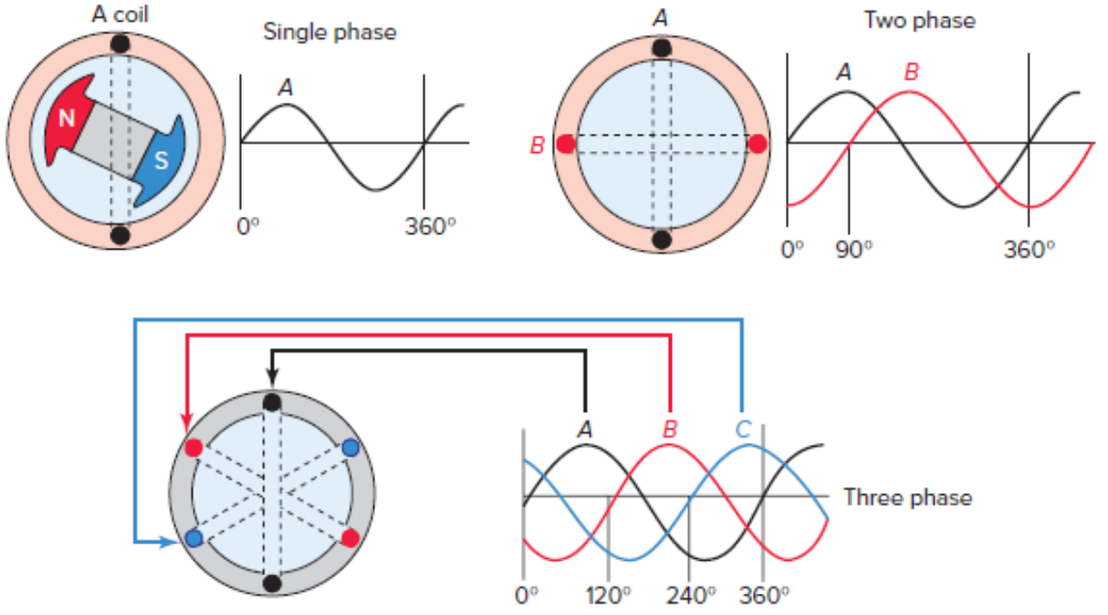


Photo source: [9] - https://blog.kakaocdn.net/dn/bgndHn/btrpMj11qa1/Gsg8aGOVVtfUSRohYf06Ck/img.png

Bu uchta chulg‘am orqali fazalar 1/3 T ga siljigan, bir xil amplitudali va bir xil chastotali sinusoidal toklar o‘tadi.

Bu toklarni hosil qilgan magnit maydonlarining magnit induksiyalari quyidagicha bo‘ladi:

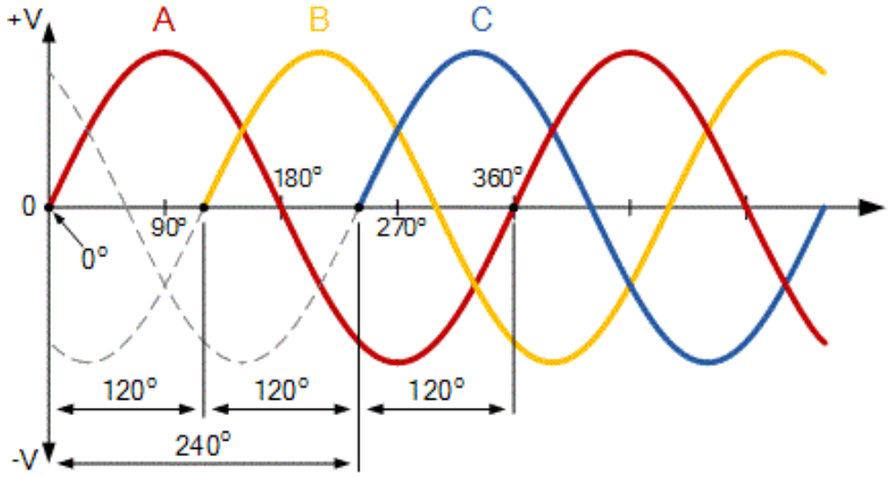


Photo source: [10] - https://electricalschool.info/uploads/posts/2019-06/1560514812_3.gif

$$U_a = U_m \sin \omega t$$

$$U_b = U_m \sin(\omega t - \frac{2\pi}{3}) \qquad (12.2)$$

$$U_c = U_m \sin(\omega t - \frac{4\pi}{3})$$

bu yerda: U_m – har bir chulg‘am o‘qi bo‘ylab yo‘nalgan magnit induksiyaning maksimal qiymati.

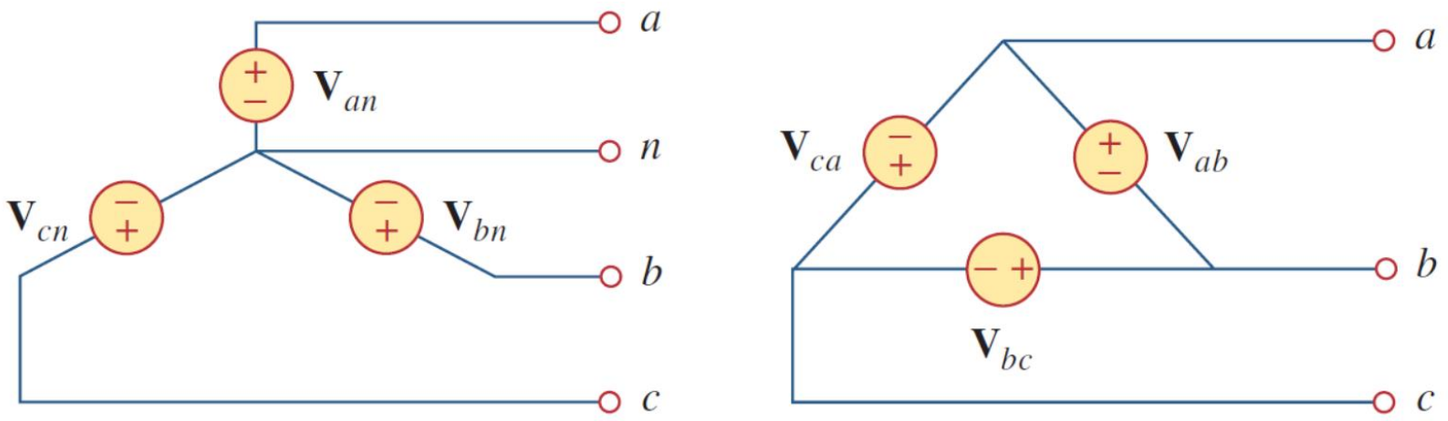
Shunday qilib, uchta bir fazali zanjirni birlashtirgan elektr zanjiri uch fazali o‘zgaruvchan tok elektr zanjiri deyiladi.

Bunday o‘zgaruvchan tok zanjirida oqayotgan tokni uch fazali tok deyiladi.

Odatda uch fazali tizim uchta yoki to‘rtta simlar (yoki uzatish liniyalari) orqali iste’molchilarga ulangan uchta kuchlanish manbasidan iborat.

Uch fazali tizim uchta bir fazali davrga teng.

Kuchlanish manbalari ***Y*** (wye) shaklda yoki ***Δ*** (uchburchak) shaklda ulanishi mumkin.



a) b)

12.8-rasm. Uch fazali kuchlanish manbalari.

a) ***Y*** shaklda ulangan manba; b) ***Δ*** (uchburchak) shaklda ulangan manba.

Agar kuchlanish manbalari bir xil amplituda va chastotaga ega bo‘lsa hamda bir-biridan 120° ga fazada farqlansa, ***kuchlanishlar muvozanatli*** deyiladi. Bu shuni anglatadiki,

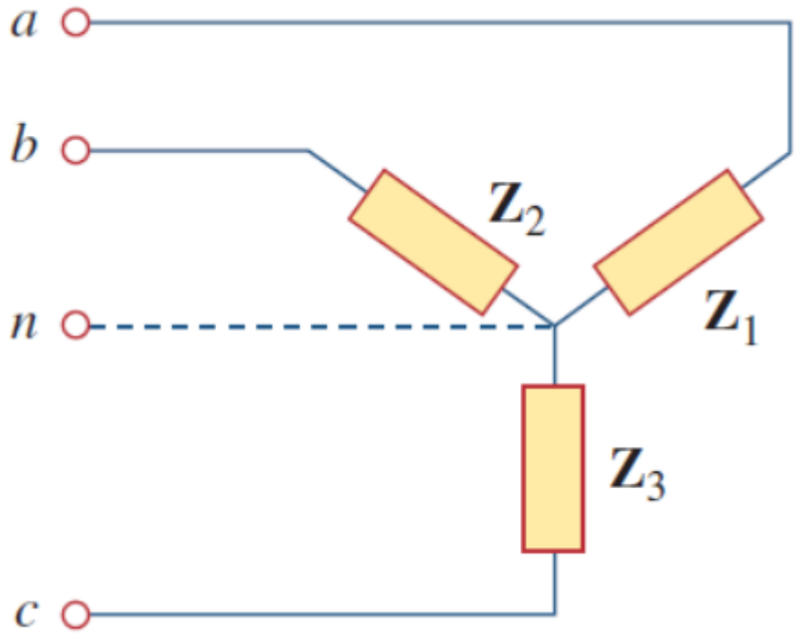
$$U_{an} + U_{bn} + U_{cn} = 0 \qquad (12.3)$$

$$|U_{an}| = |U_{bn}| = |U_{cn}| \qquad (12.4)$$

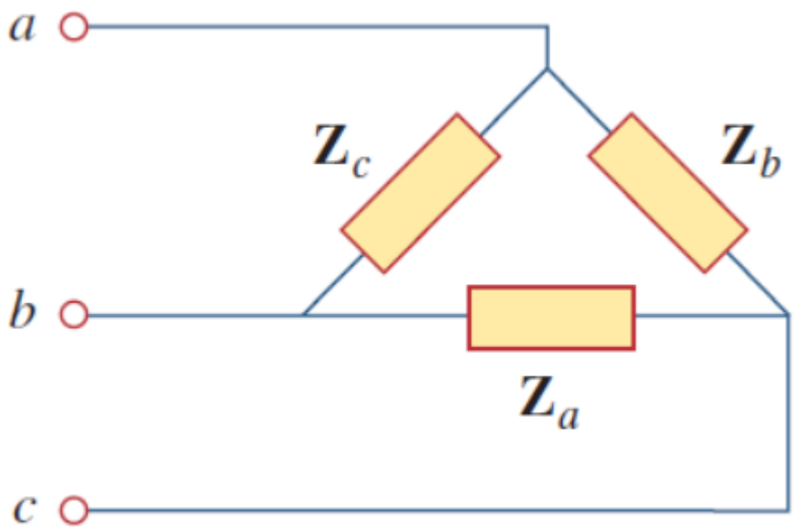
Generator chulg‘amlarini ulanishlari kabi, uch fazali yuklamalar ham so‘nggi qo‘llanilishiga qarab wye-ulangan yoki delta-ulangan bo‘lishi mumkin.

Fazali impedanslar kattalik yoki faza bo‘yicha teng bo‘lmasa, wye yoki uchburchak bilan bog‘langan yuklanish muvozanatsiz deyiladi.

Muvozanatli yuklanish - bu fazali impedanslar kattaligi bilan fazada teng bo‘lgan yuklanishdir.



a)



b)

12.9-rasm. Uch fazali yuklanishlarni mumkin bo‘lgan ikkita o‘zaro joylashuvi.

a) ***Y*** shaklda ulangan yuklamali; b) ***Δ*** (uchburchak) shaklda ulangan yuklamali.

Muvozanatlangan ***Y*** shaklda ulangan yuklanish:

$$Z_1 = Z_2 = Z_3 = Z_Y \qquad (12.8)$$

bu yerda: Z_Y – har bir fazaning yuklama impedansi.

Muvozanatlangan ***Δ*** shaklda ulangan yuklanish:

$$Z_a = Z_b = Z_c = Z_{\Delta} \qquad (12.9)$$

bu yerda: Z_{Δ} – bu holatda har bir fazaning yuklama impedansi.

$$Z_{\Delta} = 3Z_Y \qquad \text{yoki} \qquad Z_Y = \frac{1}{3}Z_{\Delta} \qquad (12.10)$$

Uch fazali manba ham, uch fazali yuklama ham ***Y***- yoki ***Δ***-ulangan bo‘lishi mumkinligi sababli, bizda to‘rtta mumkin bo‘lgan o‘zaro joylashuvlar mavjud:

- ***Y*** – ***Y*** ulanish (Y – manbali bilan Y – yuklamali);
- ***Y*** – ***Δ*** ulanish;
- ***Δ*** – ***Δ*** ulanish;
- ***Δ*** – ***Y*** ulanish.

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