EE3123 Introduction to Electric Power Systems

Overview of Power Systems

Prof. CQ Jiang

Many thanks to Prof. Michael Tse

EE3123 Introduction to Electric Power Systems

Prof. CQ Jiang
chjiang@cityu.edu.hk

LECTURES

2 hours every week

TUTORIALS

50 mins every week

PROJECTS

Starting in Oct.

9 hours of project work

No need to come to Campus

CityU CANVAS

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202509EE3123

2025/26 Semester A

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EE3123 Intro to Electric Power Sys

Welcome to EE3123!

I am Prof. CQ Jiang, the course leader and lecturer of EE3123 Intro to Electric Power System. In these Canvas pages, I will provide you with all the essential information about this course, including its aims, course synopsis, mini-project, and assessment methods.

Aims:

Covering the fundamentals of electricity distribution, this course aims to provide you with the necessary basic theory of power circuits, essential components of power systems, and the key operating principles of generating and delivering power to the final consumers. In particular, I will emphasize on some selected aspects of power systems that will allow you to understand the various processes involved in the generation and delivery of electricity, and to appreciate the key trends in the development of modern power distribution networks.

View Course Stream
View Course Calendar
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To Do

Nothing for now

Course Synopsis:

Getting started: Overview of Power System (~1 week):

The first lecture will provide an overview of modern power systems. I'll also tell you what you are expected to gain in this course.

Basic Theory and Components (~3 weeks):

The first part of this course is a review of the basic circuit theory, with emphasis on power circuits. The phasor technique will be reviewed first, and concepts of active and reactive power will be revisited. Three-phase networks and the single-phase representation will be introduced. Transformers and simple transmission line models will be used in constructing typical power networks. Typical faults in power systems will be explained in terms of the three-phase system model.

Power System Stability (~2 weeks):

Traditional power networks rely on synchronous generators for power generation. The mechanical and electrical characteristics of synchronous machines determine how the network should be controlled to maintain stability. The basic dynamics and stability of synchronous generator driven power system will be discussed in terms of a simple machine model. The Equal Area Criterion for power system stability will be explained, and applications to the analysis of post-fault stability will be illustrated.

Power Flow Analysis (~2 weeks):

A power network generates, transmits and consumes power. The process can be described in terms of power flow. The analysis of power flow is an important topic in power systems, which describes how power transmits through the network. We will discuss the formal AC power flow analysis requiring the use of suitable numerical methods for solving a set of nonlinear equations. An approximate method, called DC power flow analysis, will be introduced to study the flow process without resorting to numerical solutions. Some case studies will be presented.

Robustness and Cascading Failure (~2 weeks):

Power networks can be vulnerable to attacks and failures! Power networks can be viewed from a top-down perspective, looking at the network as a whole and how its robust operation can be affected by certain properties such as connectivity (topology) and composition of power sources. Some assessment parameters will be introduced to evaluate the vulnerability of power networks.

Course Syllabus

Overview:

This year, the weekly 3-hour lecture (2 hrs lecture + 1 hr tutorial) is scheduled on every Wednesday, from 16:00 to 18:50, in Room YEUNG Y4702. Please NOTE that ***there will be NO TUTORIAL in the first and second weeks of the semester.***

Lab / Practical Sessions:

Lab sessions will be replaced by projects. This is self-study time, and you will not be required to come to any specific venue. Moreover, you are welcome to see me during this time. Each student will be expected to complete a mini-project individually. The instruction manual and detailed procedure will be explained in mid-October during the tutorials.

Lecture Schedule:

Our tentative lecture schedule is as follows. Moreover, the tutorials following the lecture will be used to reinforce the material presented in the previous lecture.

Lecture Week	Modules
Week 1	Lecture: Overview of power systems (No tutorial in the first week)
Week 2, 3	Lecture: Basic AC power circuits and components (No tutorial in the second week, starting in the third week)
Week 4	Lecture: Three-phase power circuit analysis (1 hr tutorial + Q&A session)
Week 5	Lecture : Three-phase power circuit analysis (Tutorials will be used as Q&A/practice classes.)
Week 6, 7	Lecture: Power system stability + TEST (week 6) (Tutorials will be used for Project briefings (week 7). Essential information is provided in a

Project:

You will be required to perform a mini-project individually as part of the practical training (replacing lab sessions). Details will be provided on the Assignment Page with an assignment entitled Mini-Project. The mini-project serves as the practical component of the course. You are expected to spend 9 hours in this mini-project with a detailed and informative investigation of the specific applications.

Assessment:

Continuous assessment will account for 50% of the final assessment marks, including Assignments, quizzes/tests and project reports. The ***written exam*** will account for 50% of the final assessment marks. More details please refer to the course syllabus:

https://www.cityu.edu.hk/catalogue/ug/current/course/EE3123.htm

Teaching Assistants:

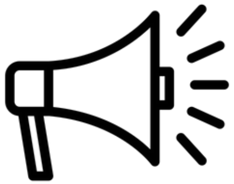
If you have any questions about this course, you may directly send an email to our TAs or me.

WANG Yibo (PhD), yibo.wang@my.cityu.edu.hk

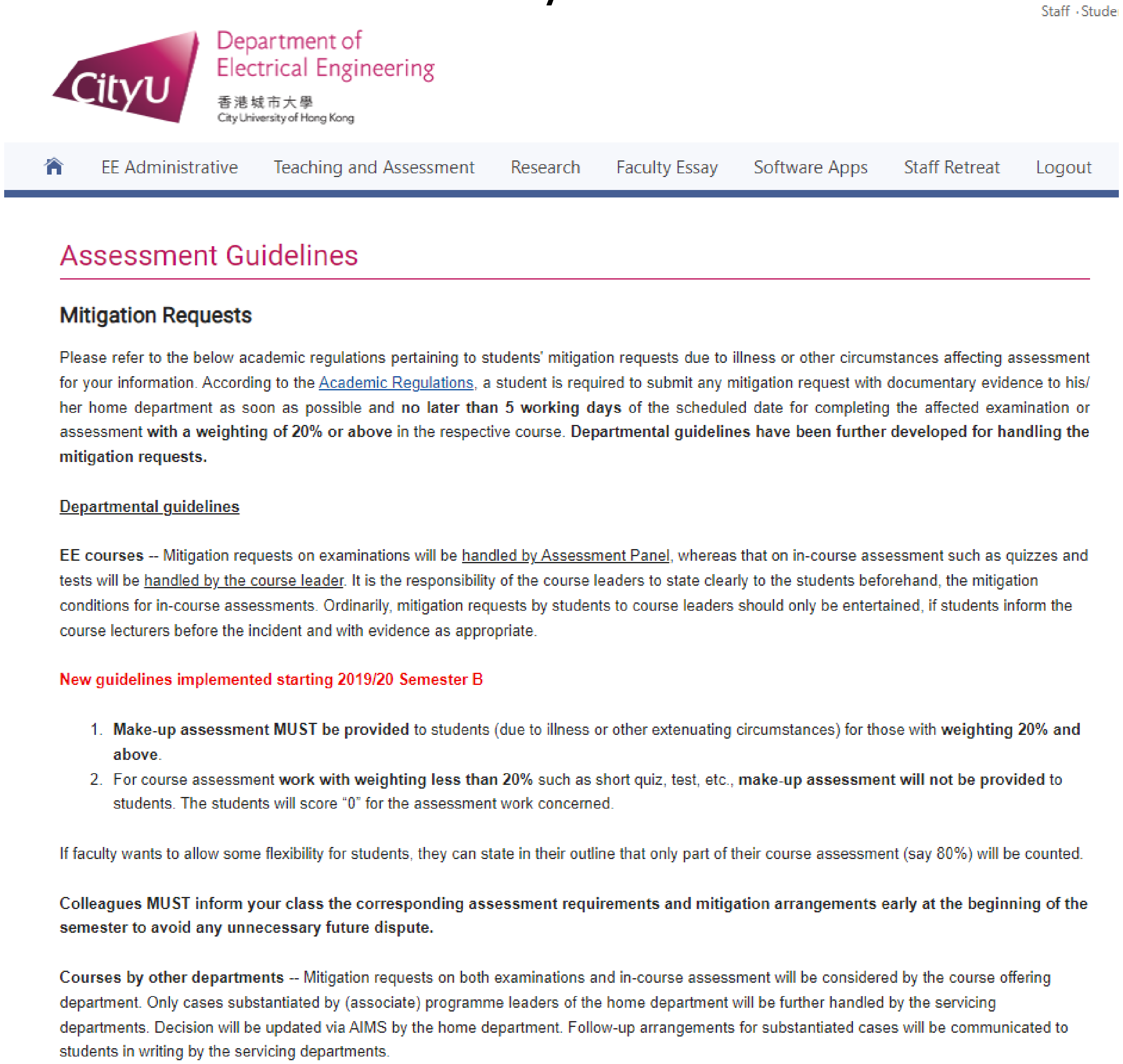
EE3123 Introduction to Electric Power Systems

A special page will be created for the mini project on CANVAS.

Please visit CANVAS frequently to get updated news.



Announcements will be made from time to time.



Staff · Stude

Department of Electrical Engineering

香港城市大學
City University of Hong Kong

EE Administrative | Teaching and Assessment | Research | Faculty Essay | Software Apps | Staff Retreat | Logout

Assessment Guidelines

Mitigation Requests

Please refer to the below academic regulations pertaining to students' mitigation requests due to illness or other circumstances affecting assessment for your information. According to the Academic Regulations, a student is required to submit any mitigation request with documentary evidence to his/her home department as soon as possible and **no later than 5 working days** of the scheduled date for completing the affected examination or assessment **with a weighting of 20% or above** in the respective course. **Departmental guidelines have been further developed for handling the mitigation requests.**

Departmental guidelines

EE courses -- Mitigation requests on examinations will be handled by Assessment Panel, whereas that on in-course assessment such as quizzes and tests will be handled by the course leader. It is the responsibility of the course leaders to state clearly to the students beforehand, the mitigation conditions for in-course assessments. Ordinarily, mitigation requests by students to course leaders should only be entertained, if students inform the course lecturers before the incident and with evidence as appropriate.

New guidelines implemented starting 2019/20 Semester B

1. **Make-up assessment MUST be provided** to students (due to illness or other extenuating circumstances) for those with **weighting 20% and above**.
2. For course assessment **work with weighting less than 20%** such as short quiz, test, etc., **make-up assessment will not be provided** to students. The students will score "0" for the assessment work concerned.

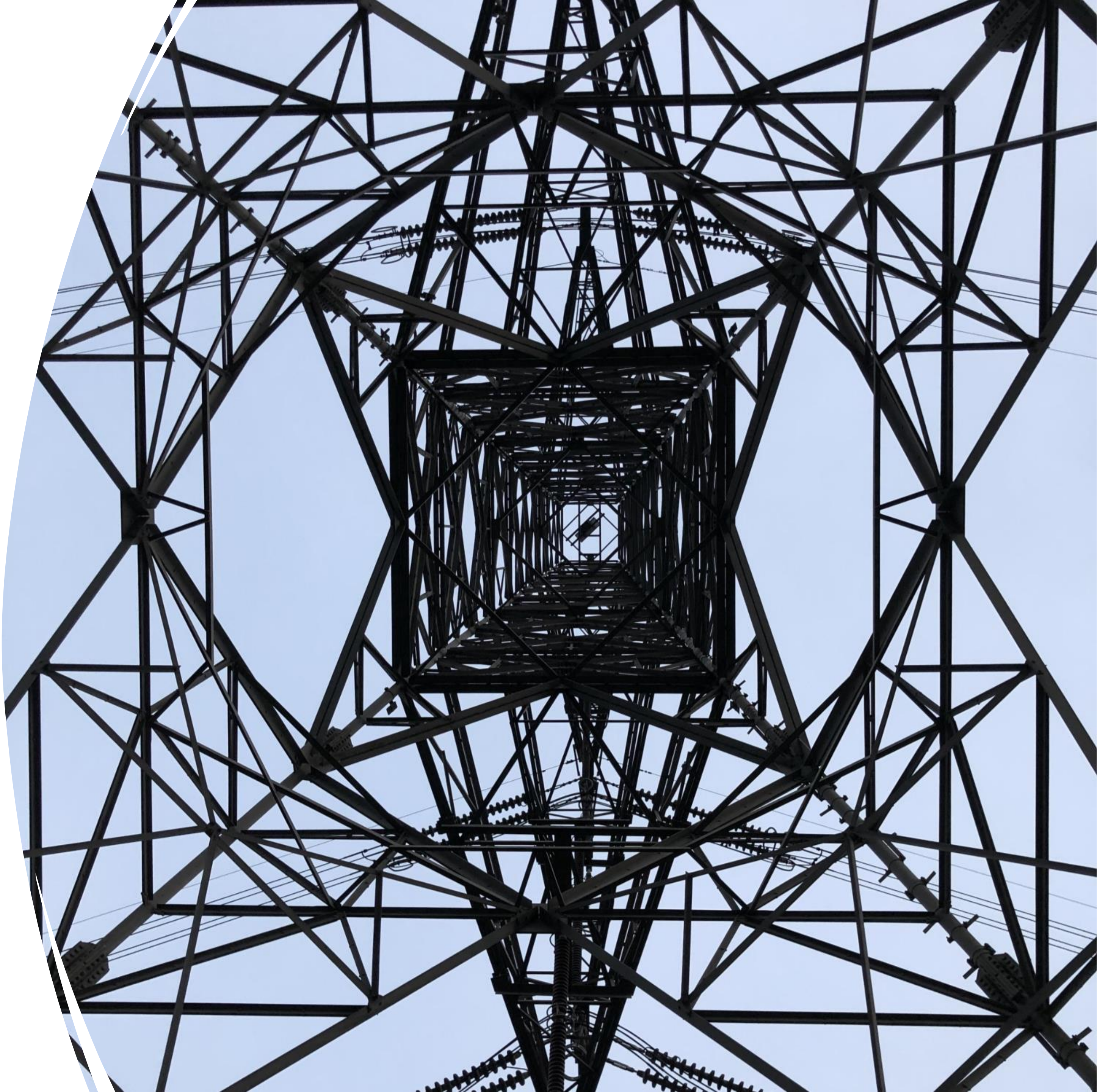
If faculty wants to allow some flexibility for students, they can state in their outline that only part of their course assessment (say 80%) will be counted.

Colleagues MUST inform your class the corresponding assessment requirements and mitigation arrangements early at the beginning of the semester to avoid any unnecessary future dispute.

Courses by other departments -- Mitigation requests on both examinations and in-course assessment will be considered by the course offering department. Only cases substantiated by (associate) programme leaders of the home department will be further handled by the servicing departments. Decision will be updated via AIMS by the home department. Follow-up arrangements for substantiated cases will be communicated to students in writing by the servicing departments.

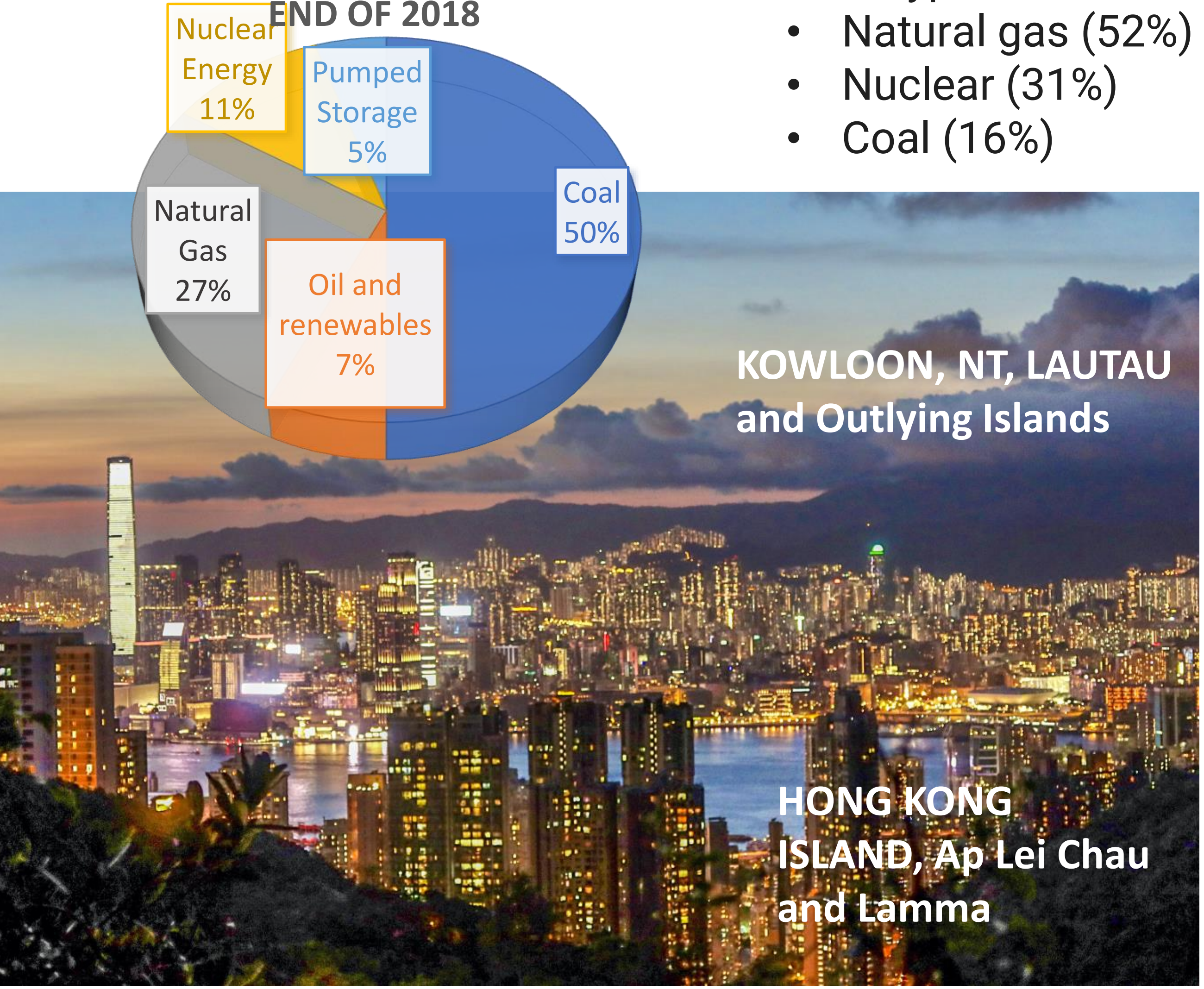
Contents

- Basic understanding of power systems (taking HK as example)
- Power system structure: generation, transmission and distribution
- Power system operation and safety



TOTAL CAPACITY of 12,369 MW

PERCENTAGE OF INSTALLED CAPACITY OF HONG KONG AT END OF 2018



CLP Electricity Output by Generation Fuel Type in 2024

- Natural gas (52%)
- Nuclear (31%)
- Coal (16%)

HK Electric Electricity Output by Generation Fuel Type in 2025

- Natural gas (68%)
- Coal (32%)

CLP 中電

Castle Peak Power Station (4,108 MW, 46%)

Penny's Bay Power Station (300 MW, 3%)

Black Point Power Station (3,175 MW, 35%)

Guangdong Daya Bay Nuclear Power Station (1577 MW, 18%)

Guangzhou Pumped Storage Power Station (600MW, 7%)

港燈 HK Electric

Lamma Power Station (3082.2 MW)

Hong Kong Energy Statistics

Hong Kong Energy Statistics Annual Report

2024 Edition

(Release Date: 29 April, 2025)

Chart | Table

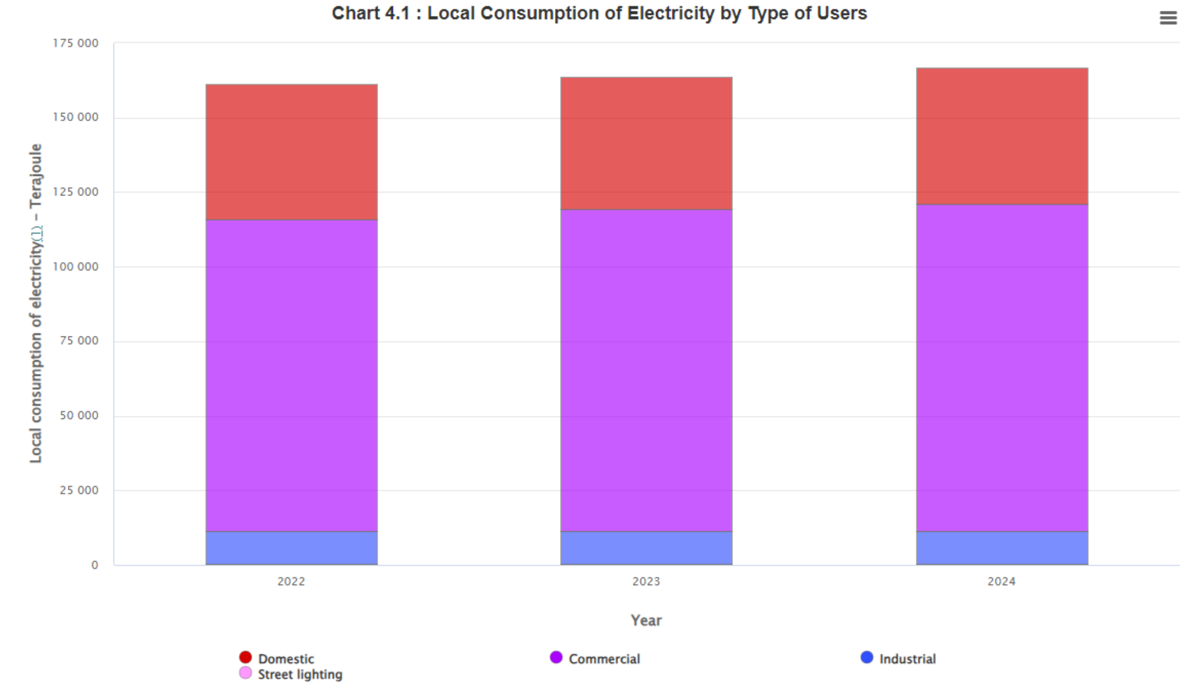


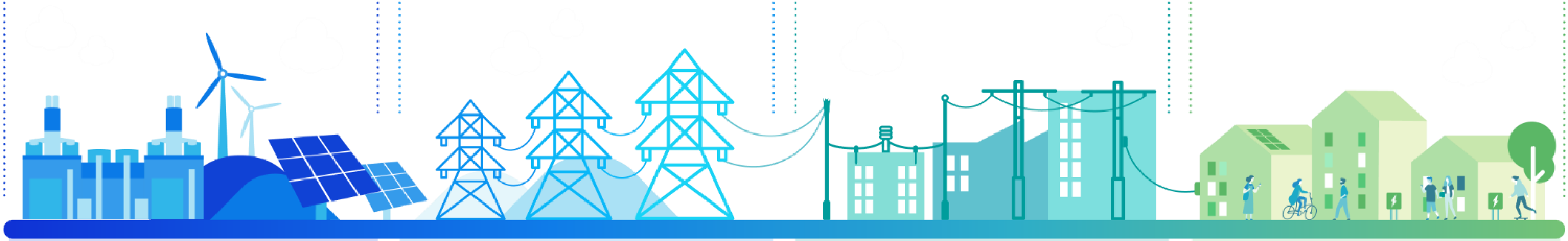
Table 3.2 : Quantity of Imports of Coal Products by Supplier

		Quantity of imports		
		Tonnes		
Type of coal products		Steam coal and other coal	Wood charcoal	Anthracite
Year	Countries/territories			
2024	Indonesia	3 807 913	47	0
	Canada	635 447	0	0
	Australia	165 100	0	0
	Colombia	159 343	0	0
	Vietnam	0	1 062	703
	Netherlands	1 343	0	0
	Thailand	0	1 143	0
	The mainland of China	0	69	705
	Malaysia	0	476	0
	Others	853	122	0
	Total	4 769 999	2 919	1 408

CLP Sustainability Report 2019

How power is delivered to our home

Generation | **Transmission** | **Distribution** | **Customers**



Generation
- Design, build, operate and invest in centralised and decentralised power stations and generation facilities
- Procure adequate and appropriate fuel and energy resources from diversified sources

Transmission
- Design, build and operate transmission networks
- Enhance transmission networks to facilitate integration of more clean energy into the grid

Distribution
- Design, build and operate distribution networks
- Integrate distributed energy resources into the grid

Customers
- Develop and deploy customer-oriented, technology-enabled energy services that help customers become active participants of a power system

Optimisation of decentralised generation

AI Smart Control

Battery storage

Smart meters and digital energy management solutions

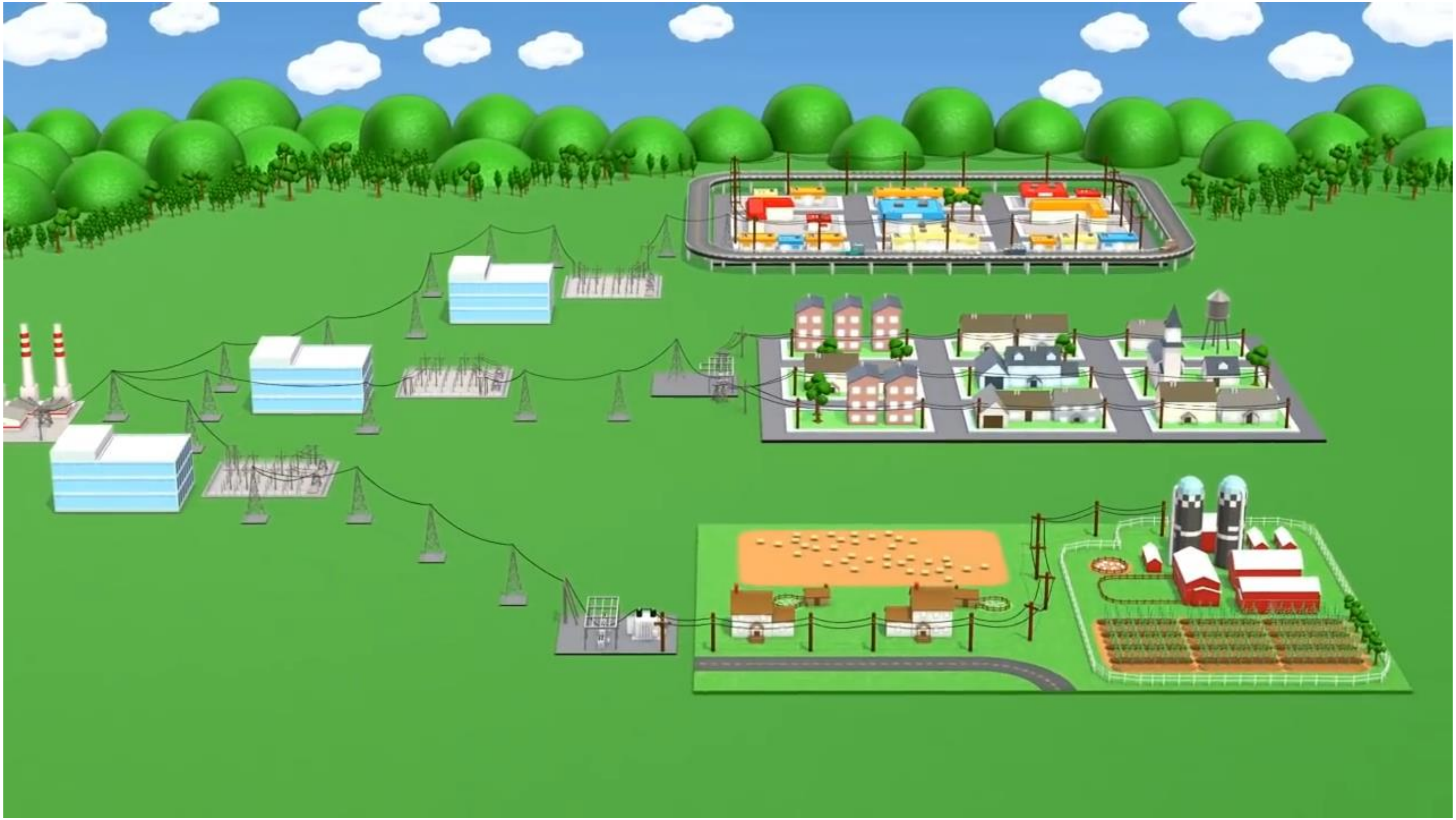
Electrification

Dynamic system balancing

Design, build and operate systems that integrate centralised and decentralised generation, and balance dynamic customer demand against different generation profiles to optimise cost efficiency, reliability and environmental performance

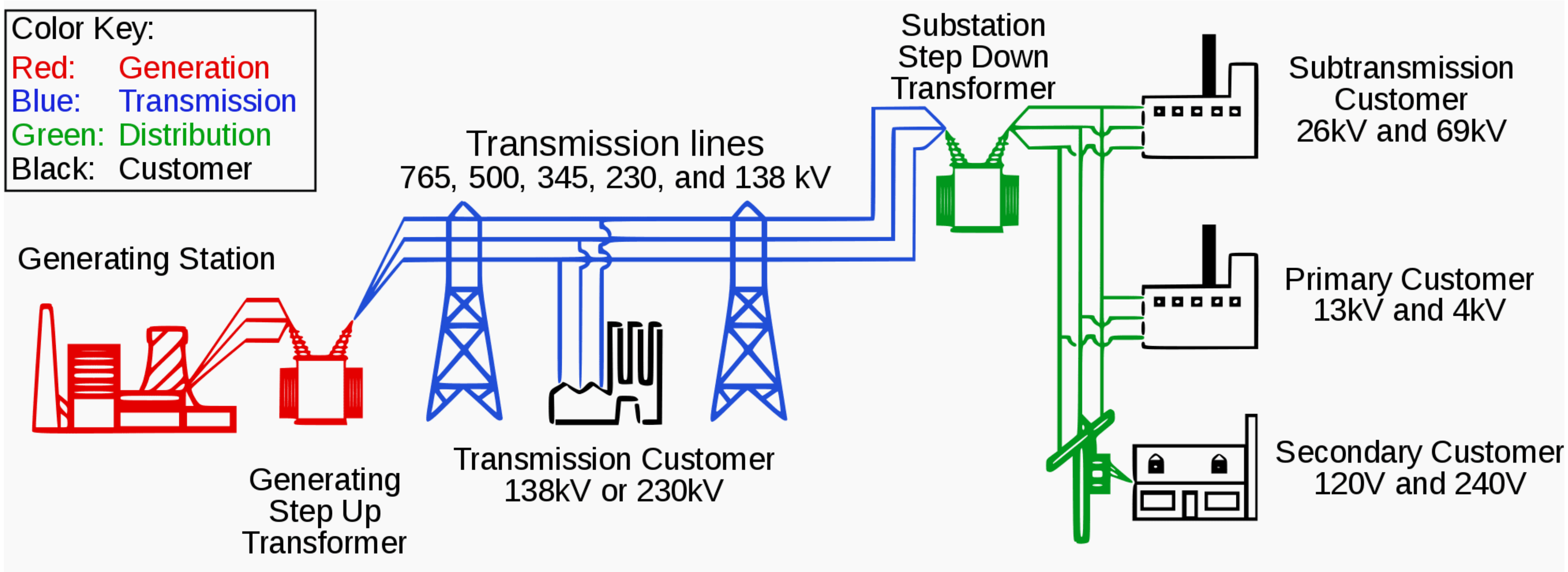
CLP Sustainability Report 2019

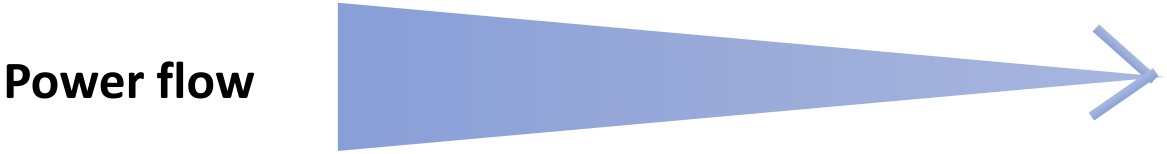
How power is delivered to our home



https://www.youtube.com/watch?v=F6YW8h8cML4&ab_channel=PSEGLongIsland

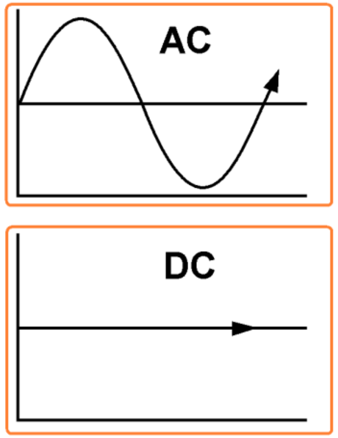
Structure of electric power generation and delivery systems



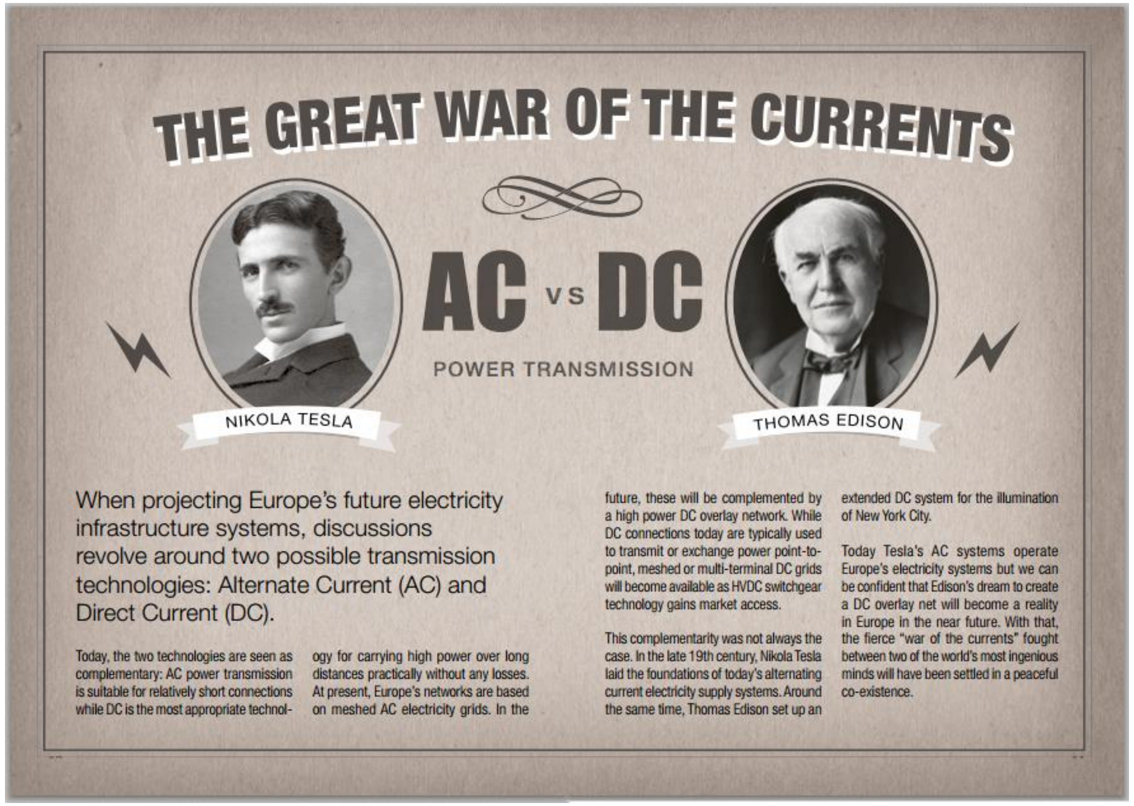


AC or DC power

Late 1800s	In 1891	After 1970s
Edison: 110 V DC power	Westinghouse: application of three-phase AC generator	High-Voltage Direct Current line (with the advent of semiconductor devices)



Comparison between AC and DC Transmission System (With their advantages and disadvantages)



THE GREAT WAR OF THE CURRENTS

AC vs DC

POWER TRANSMISSION

NIKOLA TESLA

THOMAS EDISON

When projecting Europe's future electricity infrastructure systems, discussions revolve around two possible transmission technologies: Alternate Current (AC) and Direct Current (DC).

Today, the two technologies are seen as complementary: AC power transmission is suitable for relatively short connections while DC is the most appropriate technology for carrying high power over long distances practically without any losses. At present, Europe's networks are based on meshed AC electricity grids. In the future, these will be complemented by a high power DC overlay network. While DC connections today are typically used to transmit or exchange power point-to-point, meshed or multi-terminal DC grids will become available as HVDC switchgear technology gains market access.

This complementarity was not always the case. In the late 19th century, Nikola Tesla laid the foundations of today's alternating current electricity supply systems. Around the same time, Thomas Edison set up an extended DC system for the illumination of New York City.

Today Tesla's AC systems operate Europe's electricity systems but we can be confident that Edison's dream to create a DC overlay net will become a reality in Europe in the near future. With that, the fierce "war of the currents" fought between two of the world's most ingenious minds will have been settled in a peaceful co-existence.

AC power system (from alternators):

- Pros: easy to be generated, flexible to be transmitted (power delivery with varied voltage level), current interruption, etc.
- Cons: synchronism and stability issue (frequency, voltage, angle etc.)

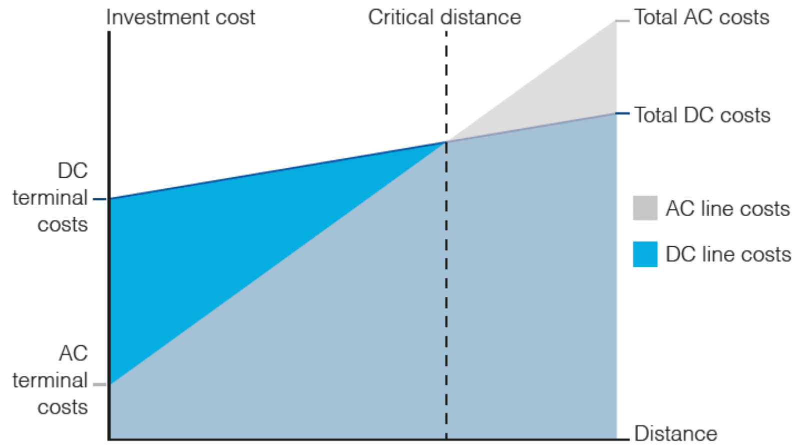
DC power system (from batteries, solar cell, fuel cell, etc.):

- Pros: simple and less stability problem (no reactive power, no synchronization issue), fewer transmission lines required over long-distance transmission (HVDC), etc.
- Cons: hard voltage transformation, not easy to cut off DC current, etc.

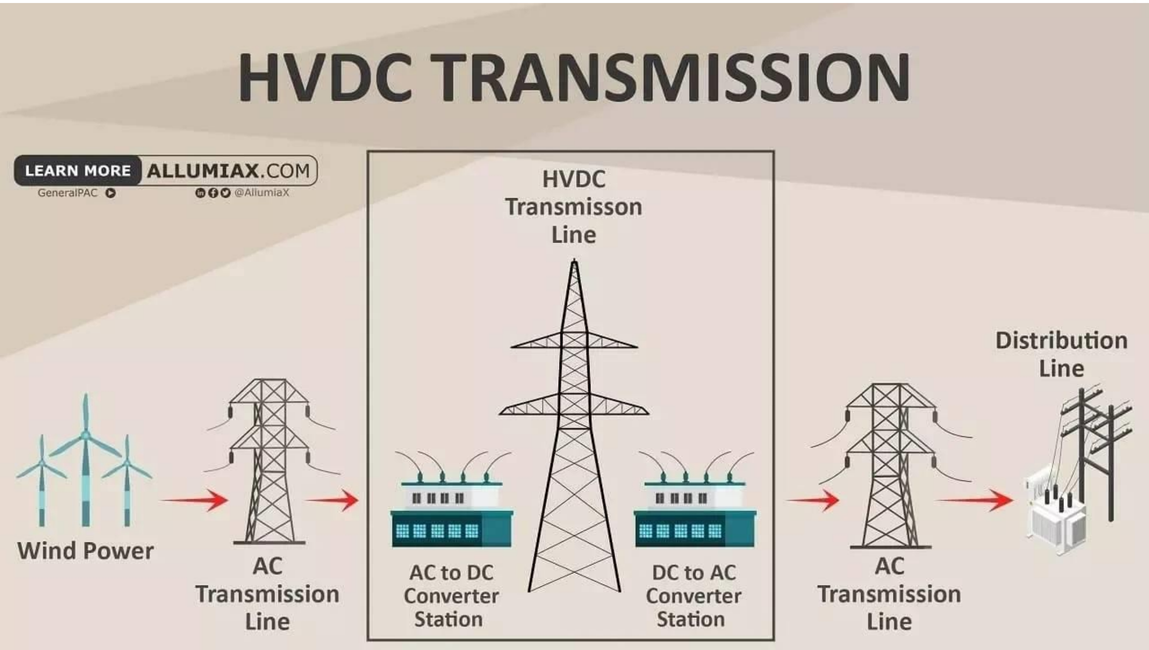
AC or DC power: Tesla and Edison

https://www.youtube.com/watch?v=wigXYgnaCfI&ab_channel=OneMinuteHistory

AC or DC power



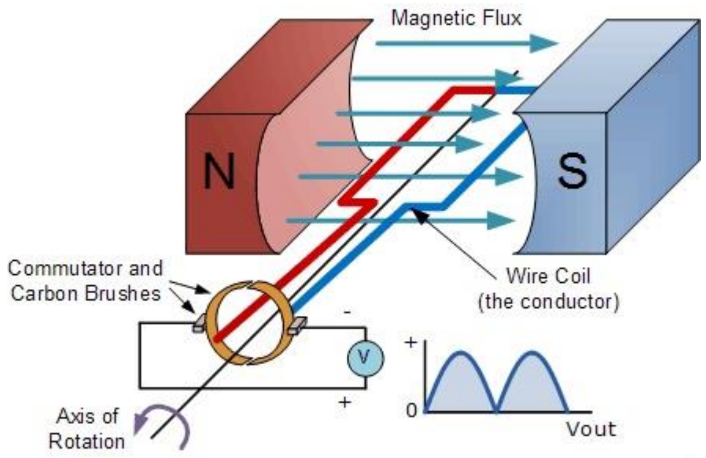
HVDC has a higher initial cost – the converter stations – but because the means of transmission (the overhead lines and the cables) are less expensive per kilometer with DC, there is a break-even distance.

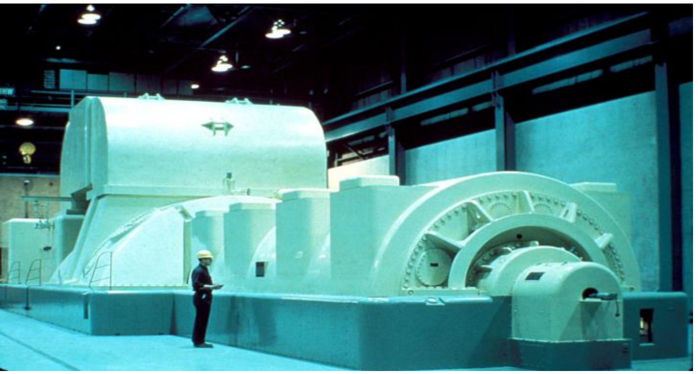


	HVAC	HVDC
Nature of Current	Alternating current (AC) flows back and forth, changing direction periodically	Direct current (DC) flows steadily in one direction without oscillation
Transmission Efficiency	Suffers from skin effect and reactive power losses, especially over long distances	Experiences lower losses due to skin effect and no reactive power losses. It is more efficient for long-distance transmission
Distance and Underwater Transmission	Suitable for shorter distances (typically up to a few hundred kilometers)	Ideal for ultra-long distances, including underwater cables (intercontinental transmission)
Converter Stations	Requires frequent converter stations along the transmission line	Requires fewer converter stations, reducing infrastructure complexity
Voltage Levels	Operates at lower voltages (typically up to 800 kV)	Can handle higher voltages (up to 1,200 kV or more)
Grid Interconnection	Easily connects to existing AC grids	Facilitates interconnection between asynchronous AC grids (different frequencies)

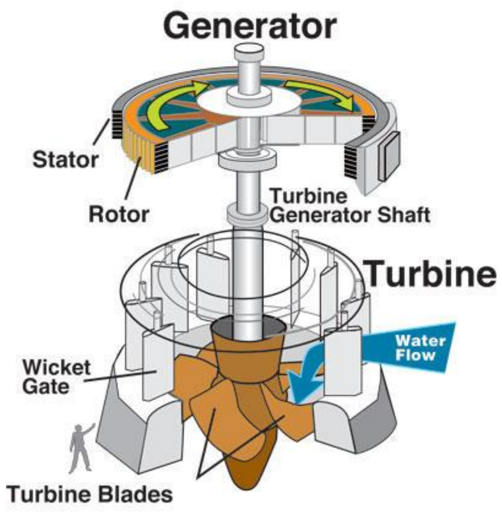
Generation

Faraday's law of induction



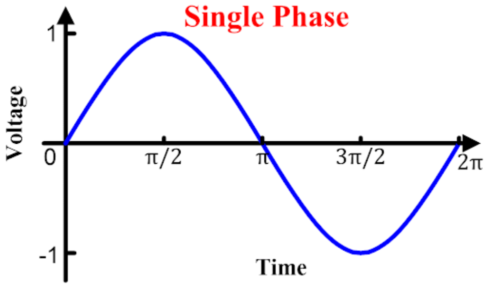


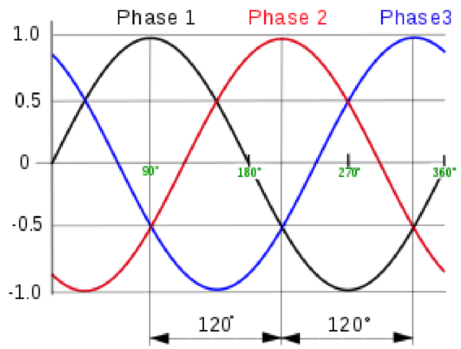
Modern steam turbine generator (STG).



- Why 50Hz/60Hz
  - engine efficiency
  - <u>less noticeable flicker (lighting)</u>
  - historical reason: the limitations of 19th century material engineering

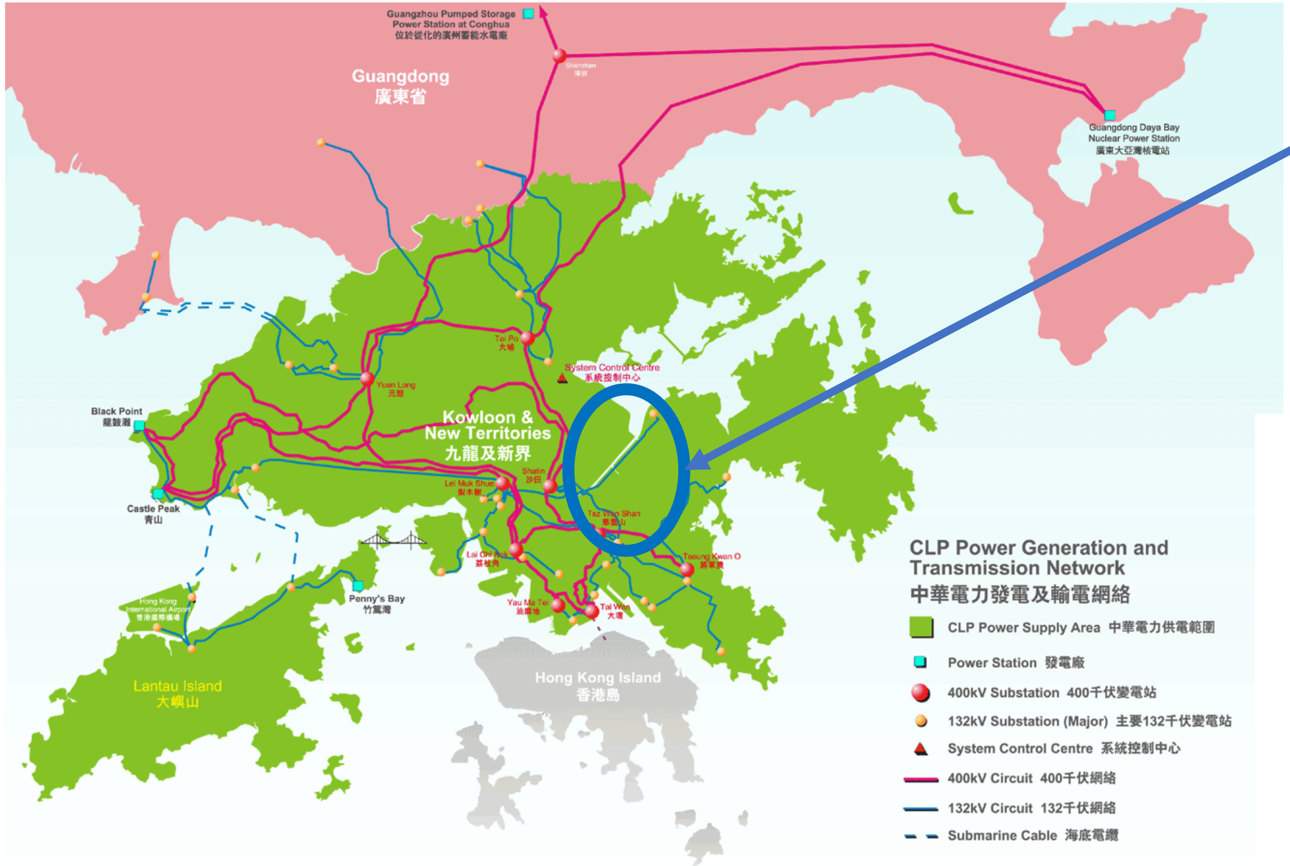
- Three-phase (T) vs single-phase generator (S)
  - T provides greater power density than S at the same amperage, keeping wiring size and costs lower.
  - T makes it easier to balance loads, minimizing harmonic currents and the need for large neutral wires.





Transmission

The Power transmission network of Hong Kong



Transmission and Distribution (June 2020 figures)

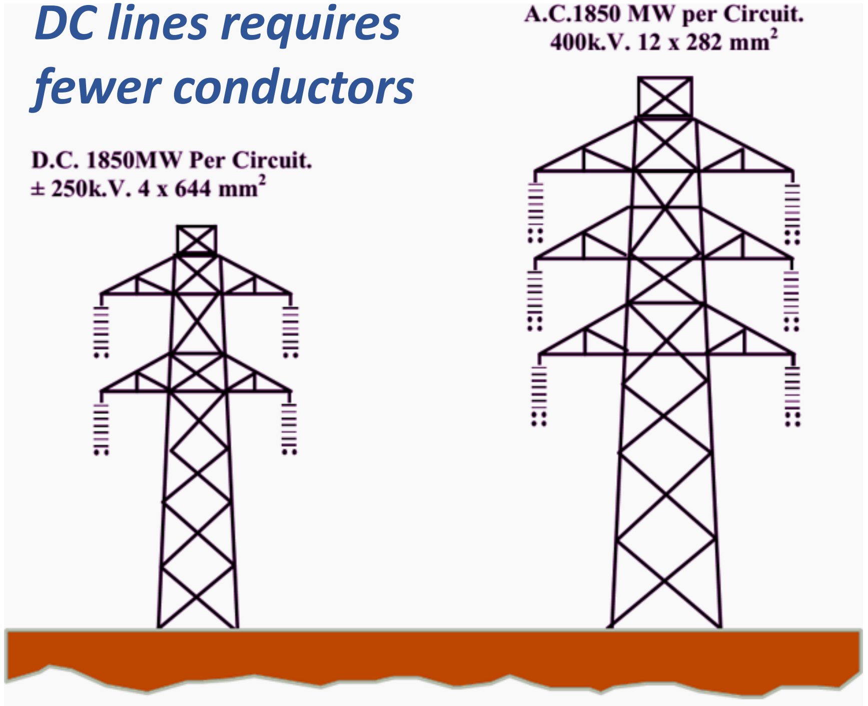
No. of primary substations	235
No. of secondary substations	14,955
Transmission and high voltage distribution lines	About 16,135 km **16,135 km**
Average network loss (2015-2019)	3.83% of total energy consumption
Average unplanned Customers Minutes Lost per year (2017–2019)	1.27 minutes (The figure will be 10.13 minutes if including the impact due to Super Typhoon Mangkhut)
Electricity supply reliability	Above 99.999% (as of December 2019)

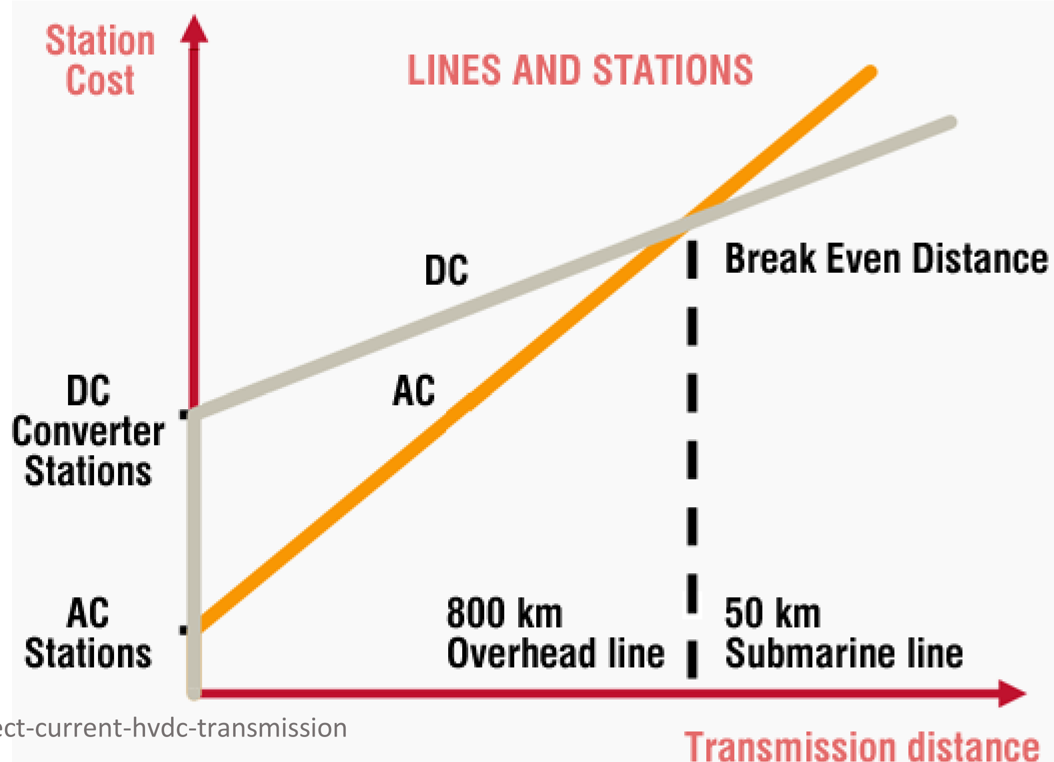
Photo source: http://www.hk-phy.org/energy/power/elect_phy04_e.html

Transmission lines

- Comparing HVDC (high voltage direct current) and HVAC (high voltage alternative current)
  - HVDC is used to transmit electricity over long or very long distance by overhead transmission lines or submarine cables, because it then becomes economically attractive over a conventional AC transmission lines.

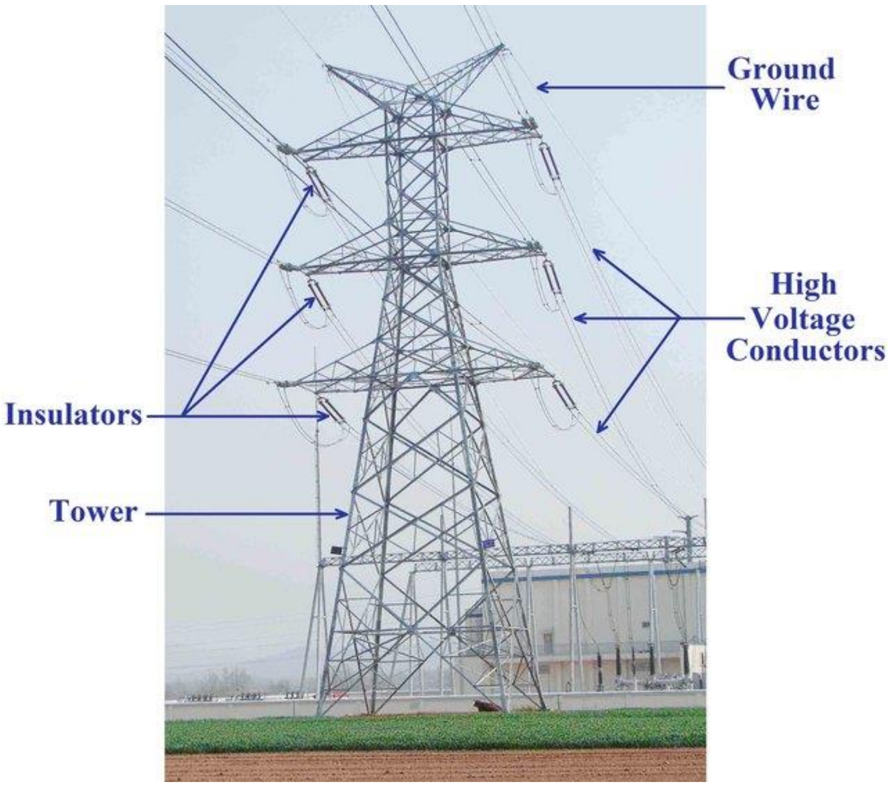
➢ ***DC lines requires fewer conductors***

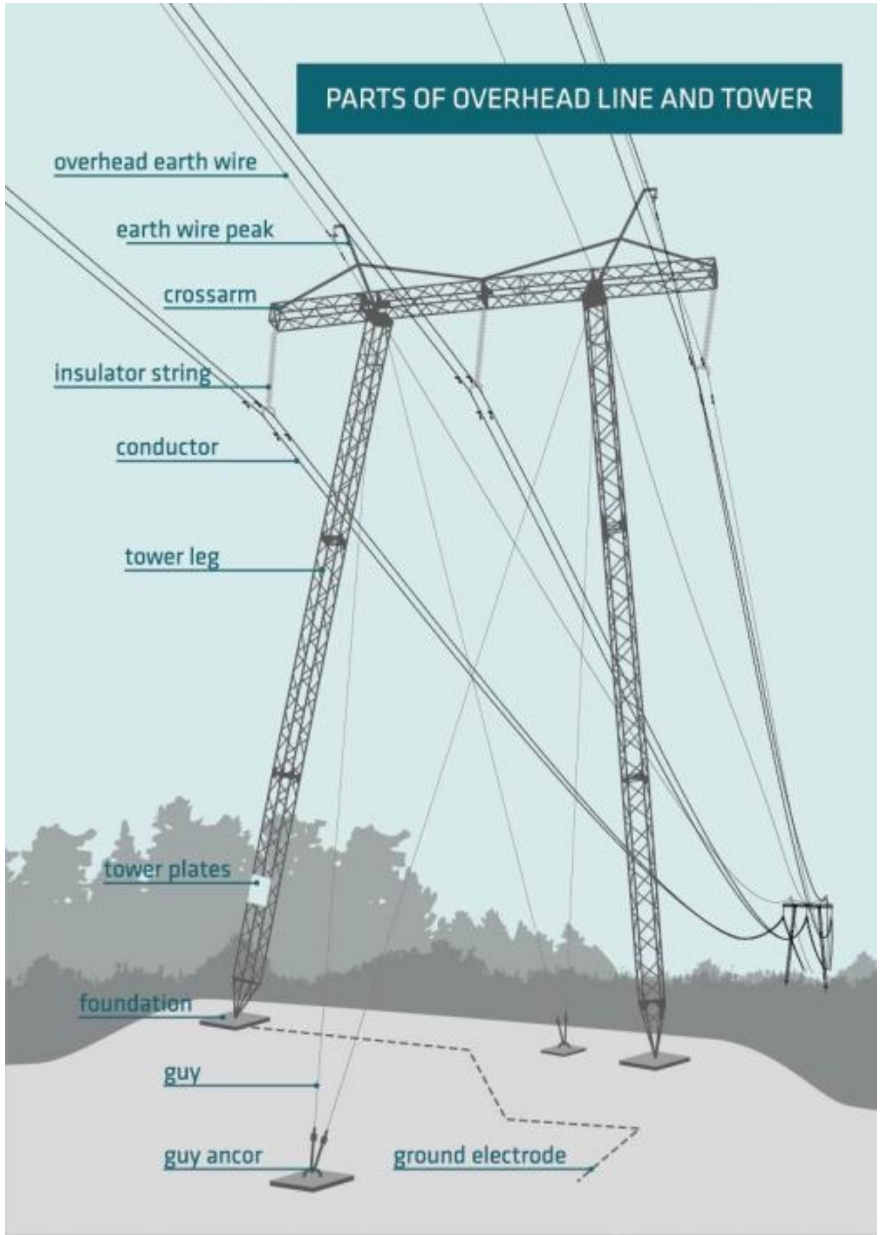


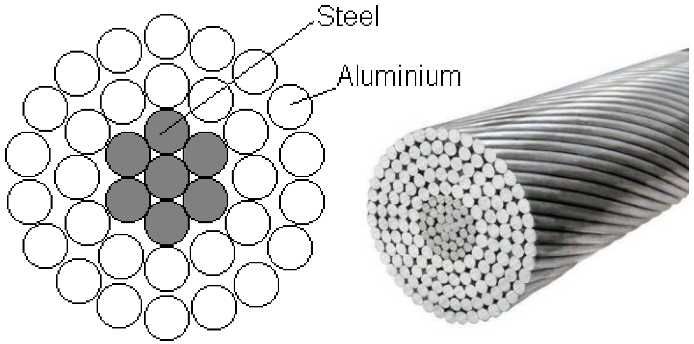


Material source: https://electrical-engineering-portal.com/analysing-the-costs-of-high-voltage-direct-current-hvdc-transmission

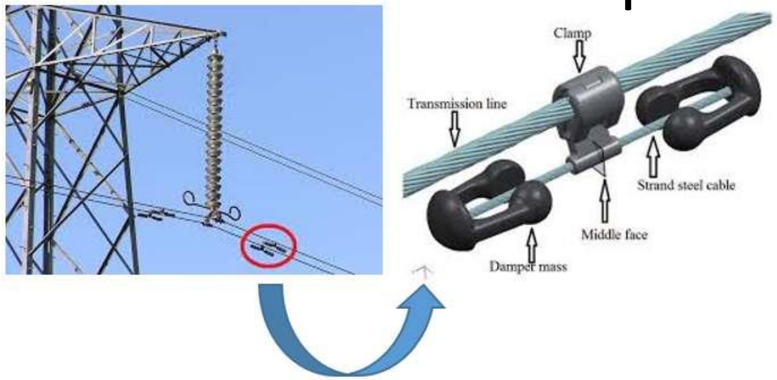
Transmission lines





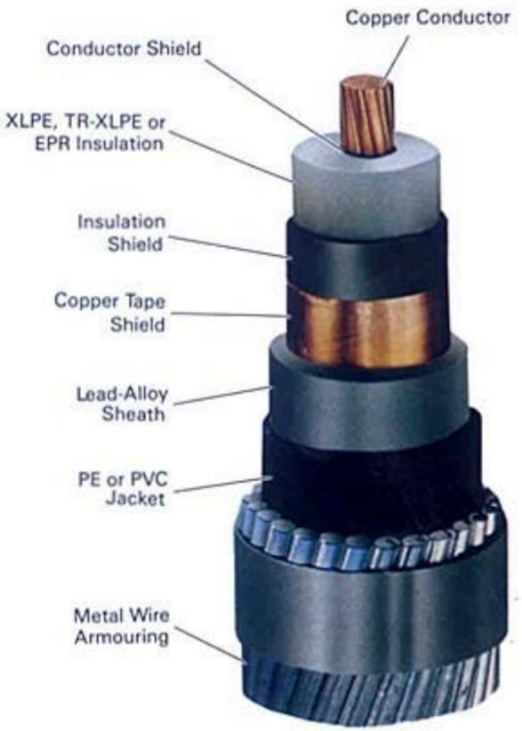


Vibration damper



Transmission lines

- Voltages as high as 500 kV
- Typically three-phase AC
- DC in some special cases



❑ Conventional cables

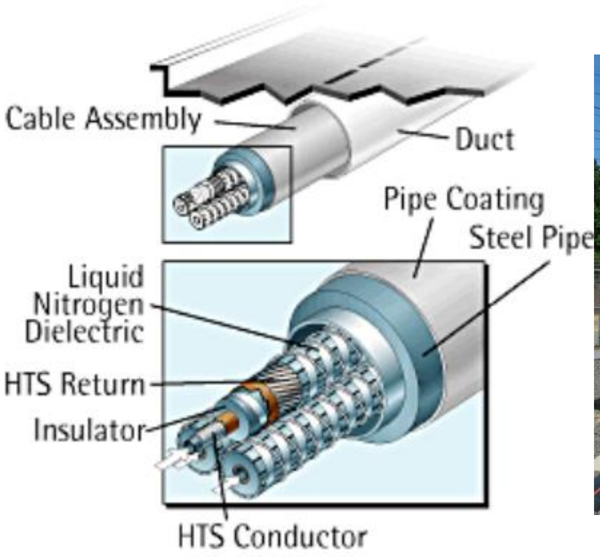
Large diameter to reduce resistance

Large insulation

❑ Superconductor cables

No resistance

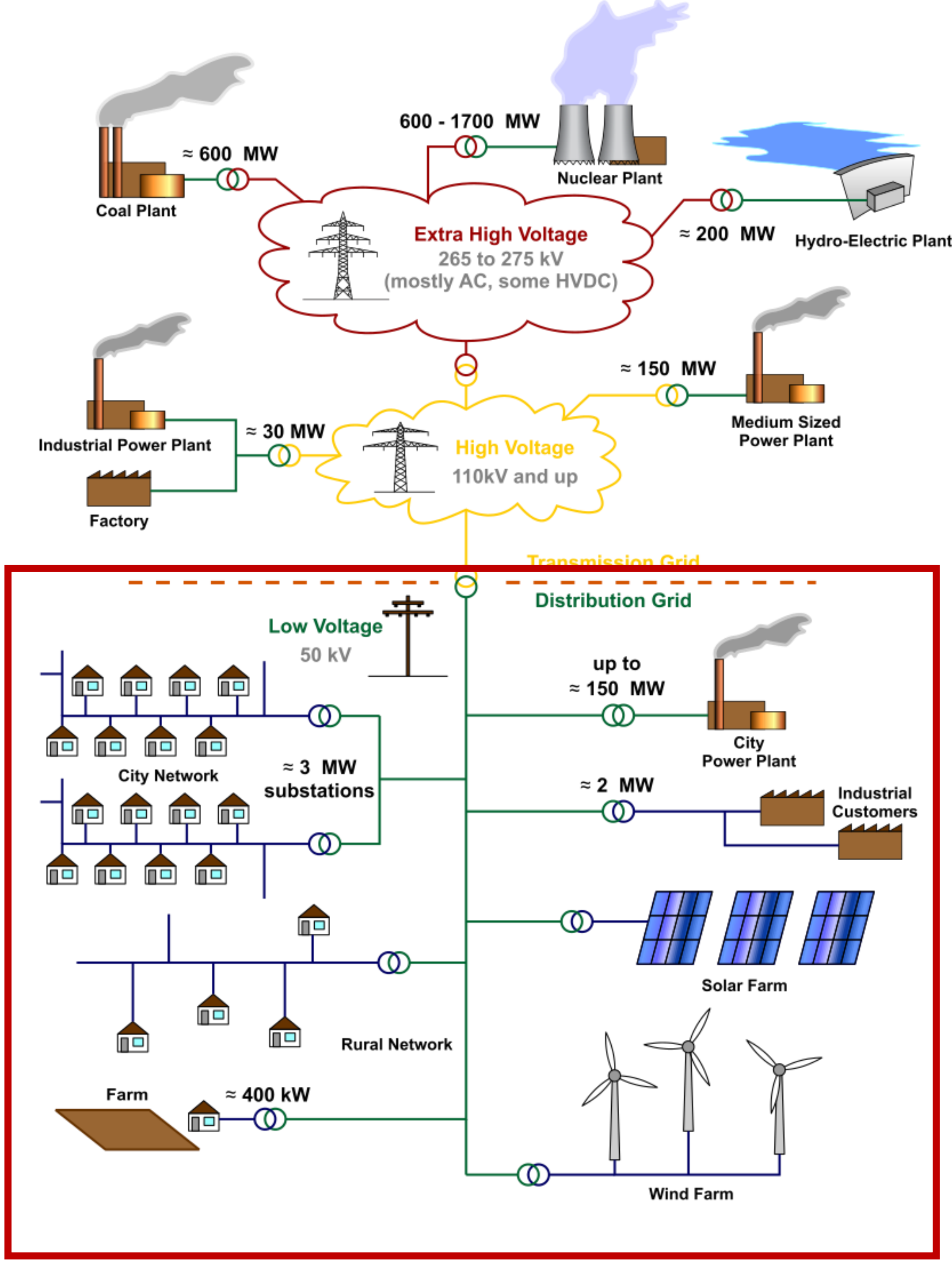
Need to be cooled



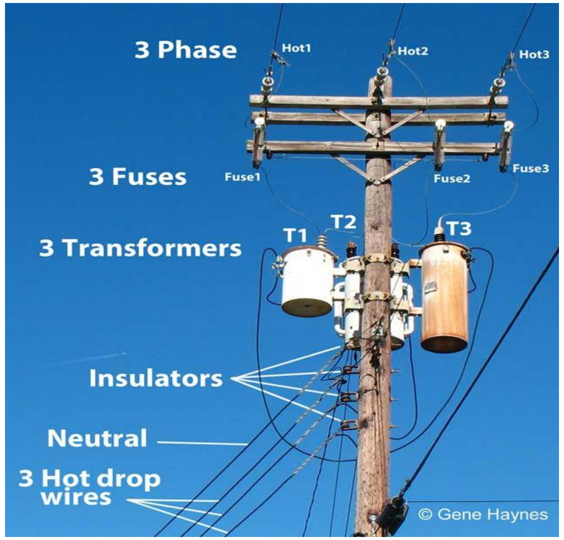
Distribution

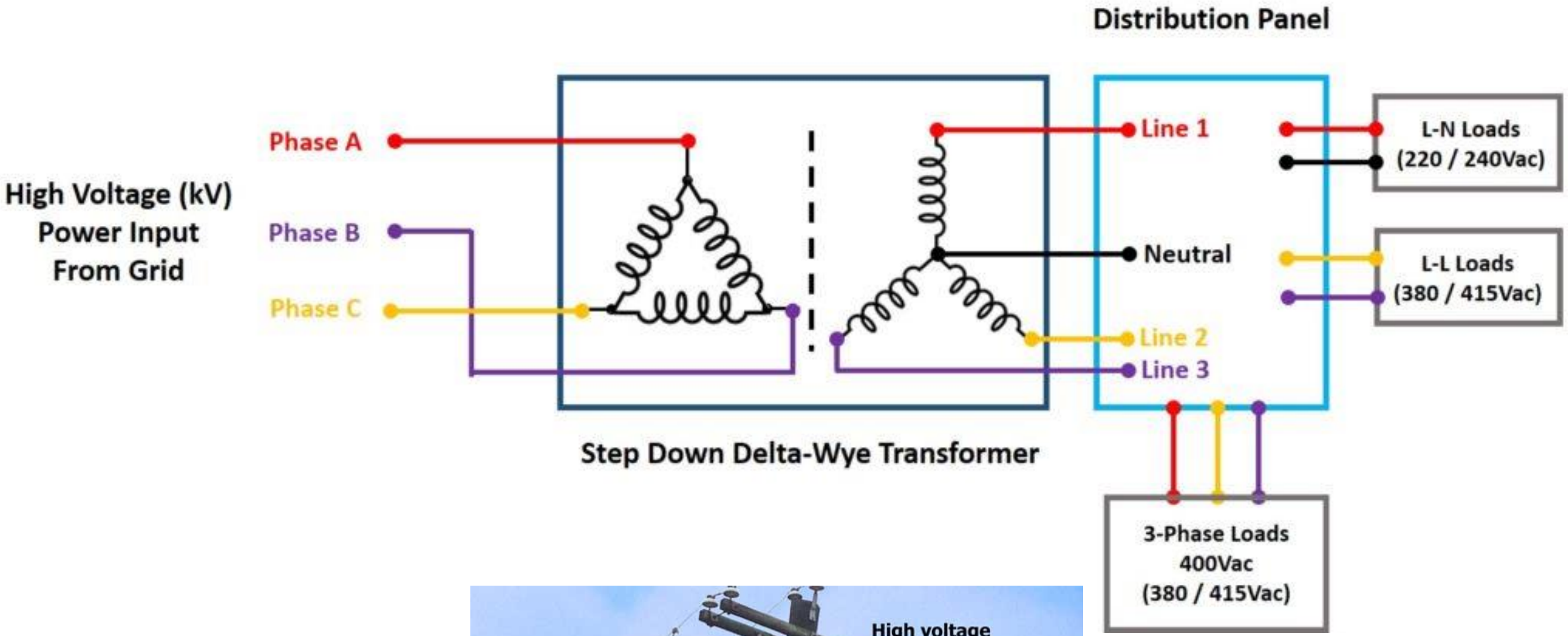
- The final stage in the delivery of electric power: from the transmission system to individual users.

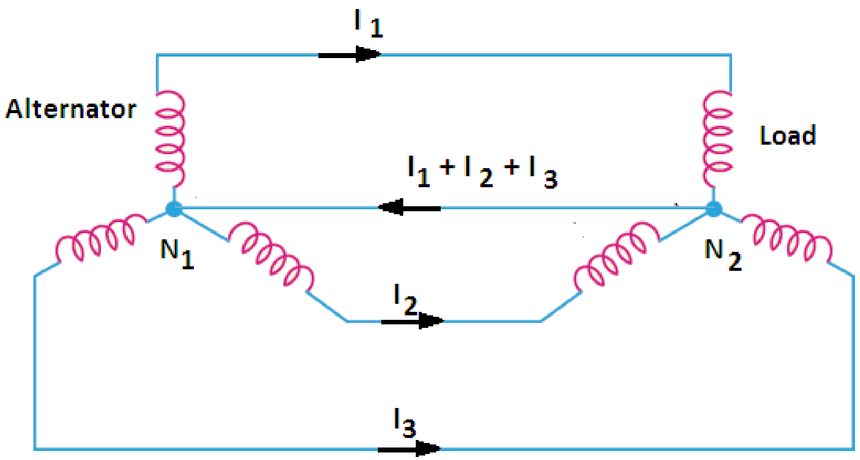
Utility pole ***v.s*** underground cables in a city



Three-phase overhead lines in local distribution

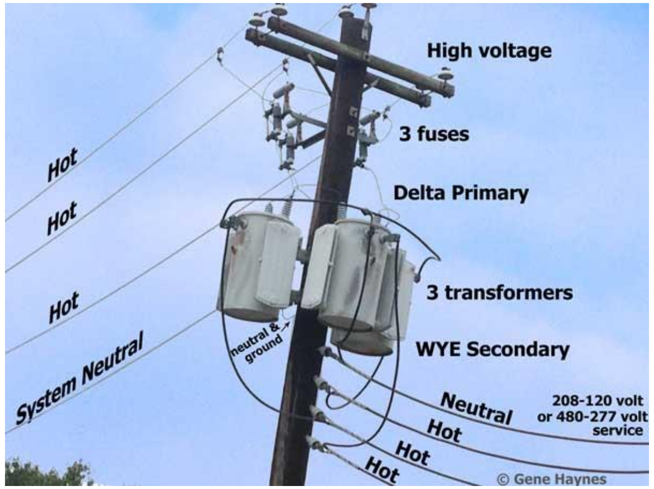






$$\frac{380\text{ V}}{\sqrt{3}} \approx 220\text{ V}$$

$$\frac{415\text{ V}}{\sqrt{3}} \approx 240\text{ V}$$



Note: if three phase loads are balanced, the neutral conductor can be removed.

Three-phase overhead lines in local distribution

High Voltage (kV)
Power Input
From Grid

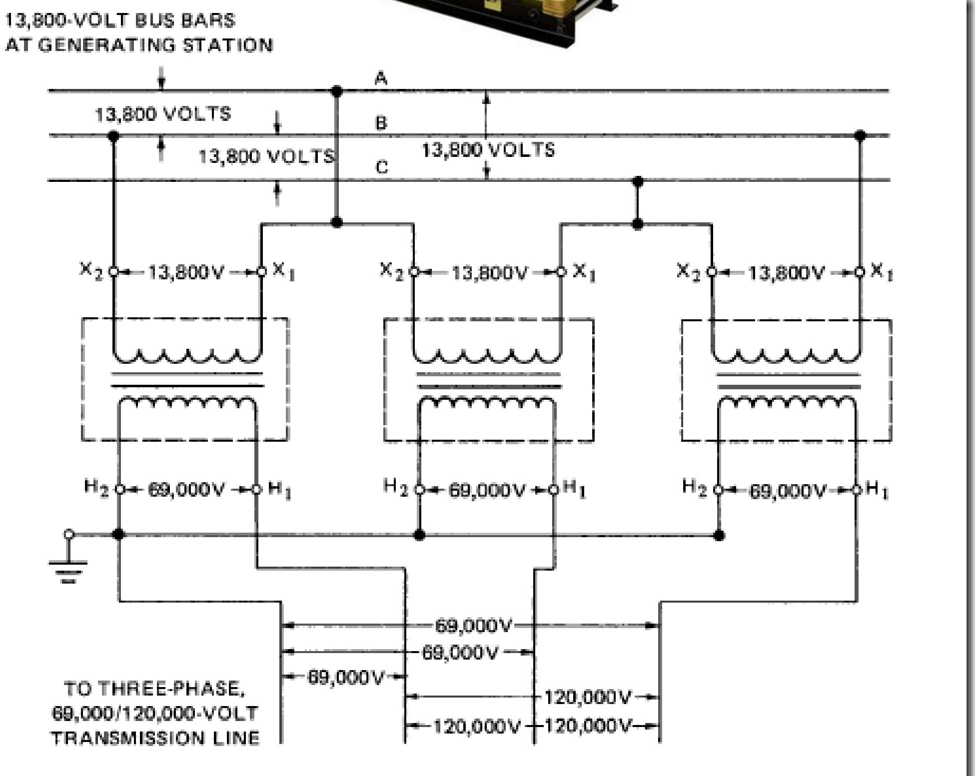
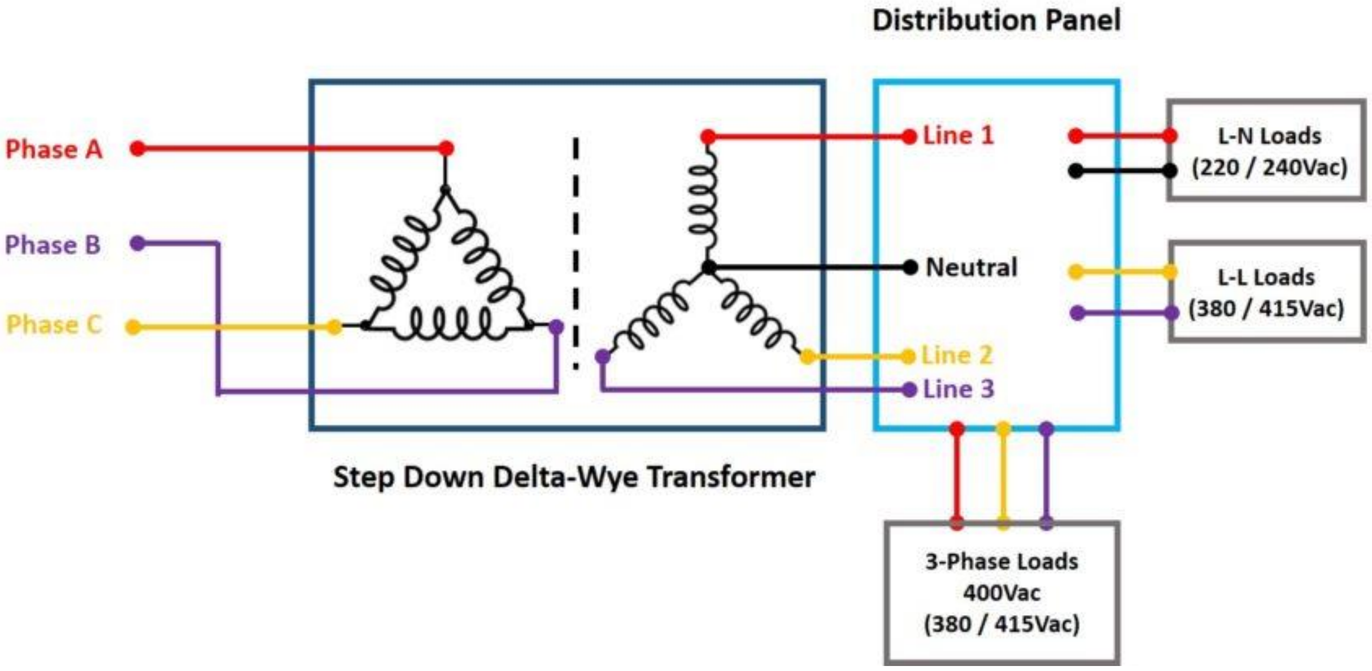
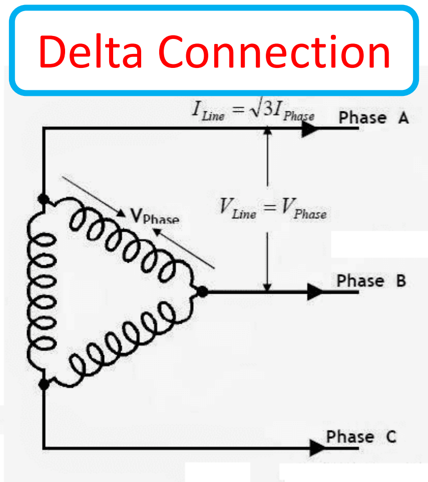
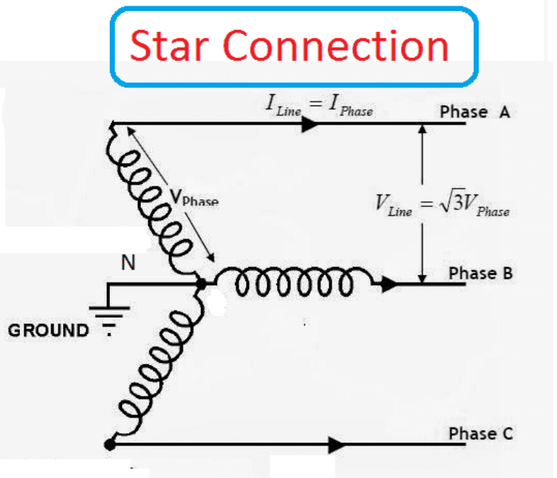


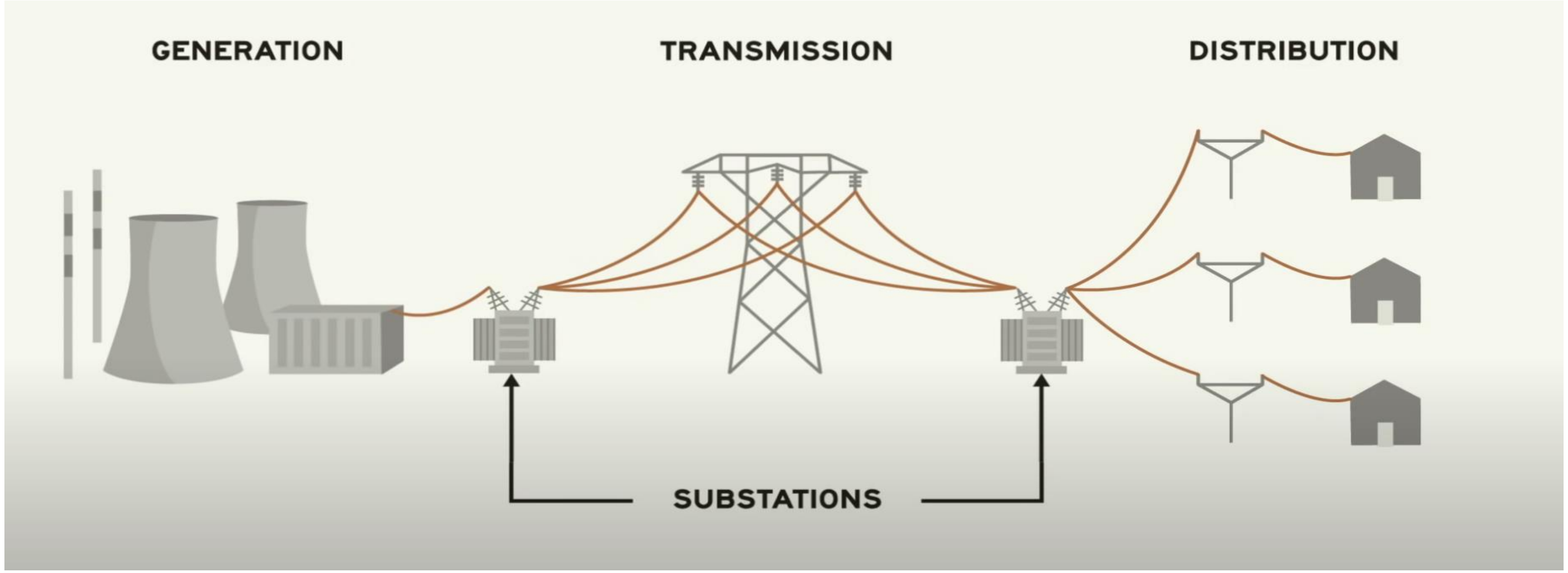
FIGURE 14–11 Delta–wye transformer bank (*Delmar/Cengage Learning*)



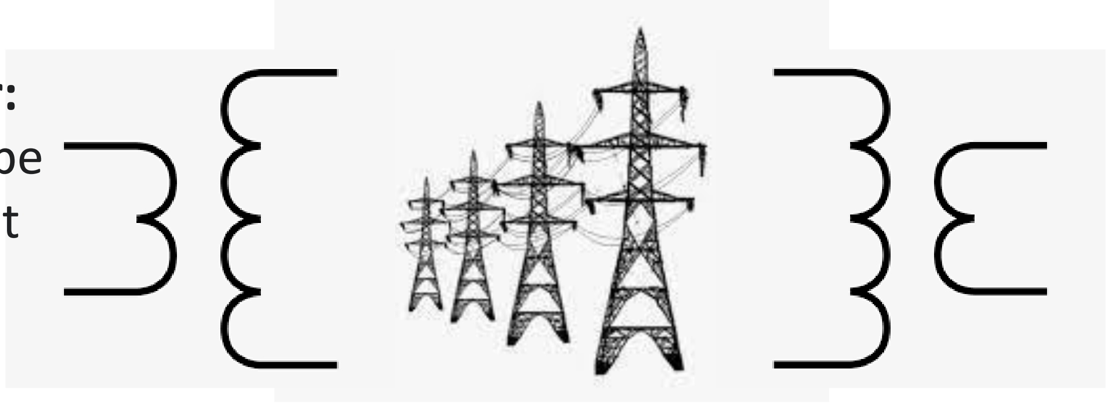




Substations: transformers



A step-up transformer: low level power must be stepped up for efficient electrical power transmission.



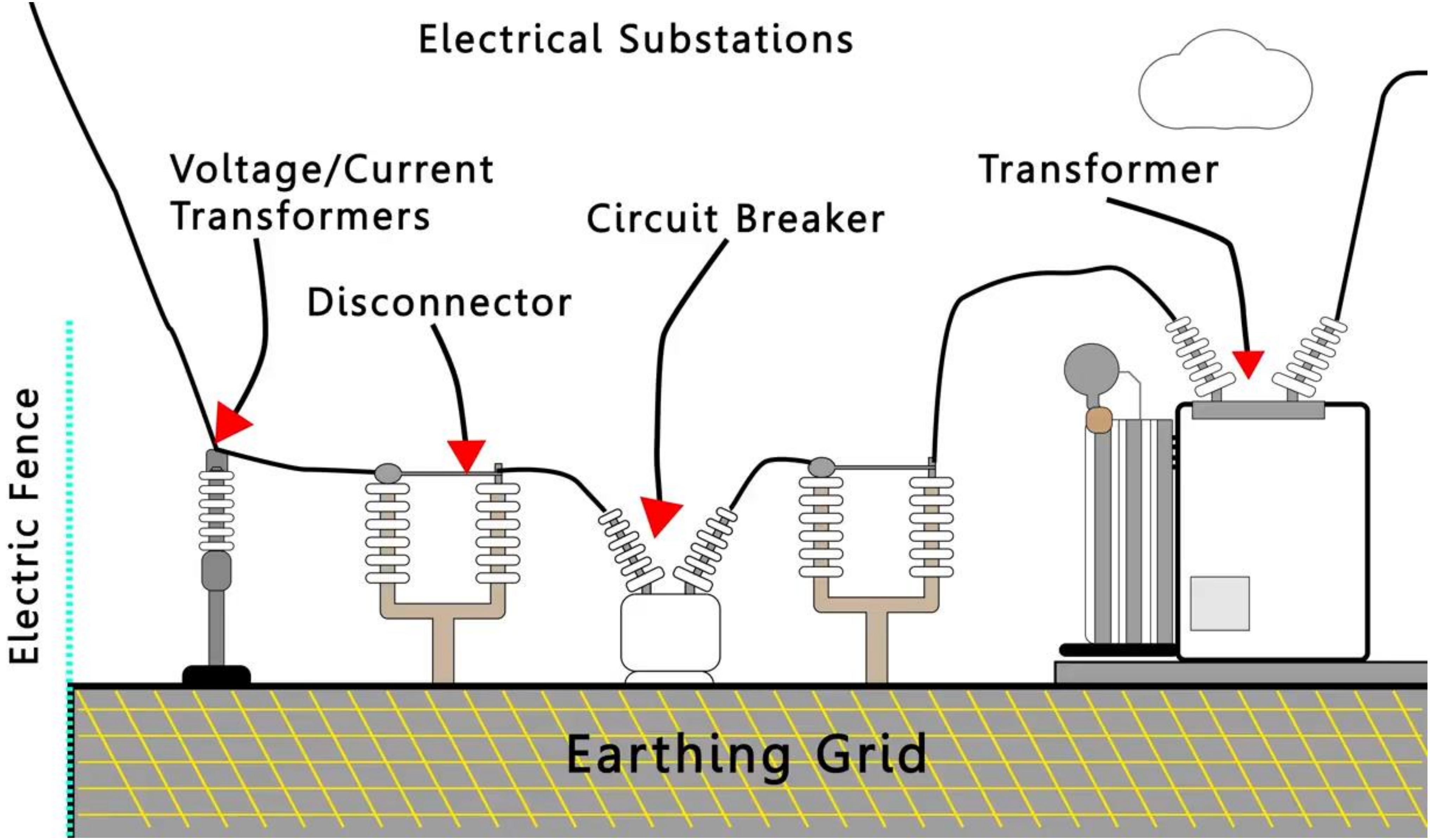
A step-down transformer: steps down the voltage for distribution purpose to domestic or commercial users.

Voltage level: **4 kV to 30 kV (depending on generator)**

500 kV, 110 kV, 230 kV

10 kV, 12 kV, 220 V, 110 V

Substations: transformers



https://www.youtube.com/watch?v=pDpIoeWDjuM&ab_channel=VisualElectric

The role of power company

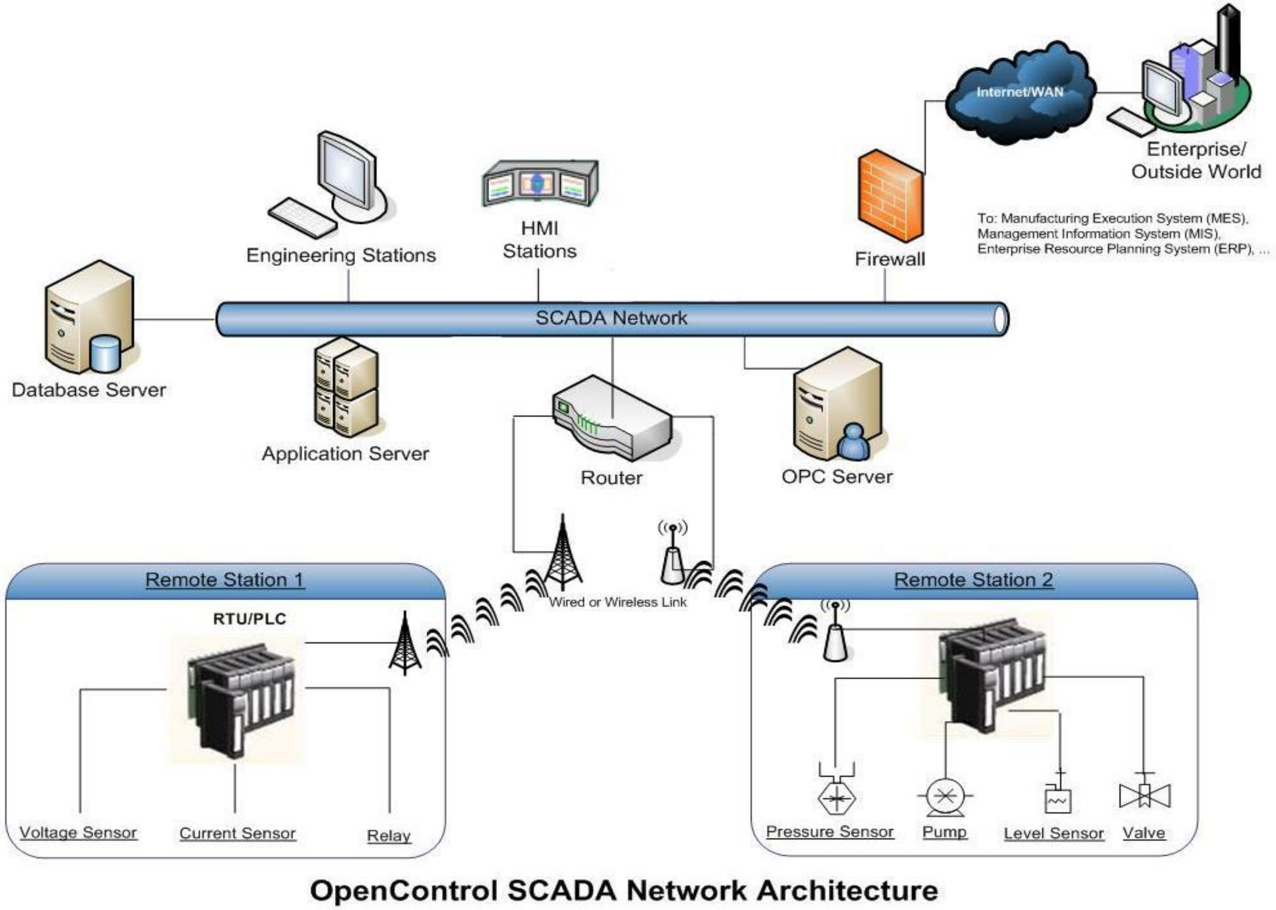
- to maintain reliable and economical (power selling and buying) operation of electric power systems
- to build smart grids: more intelligent, more efficient, and more resilient

System Control Centre monitors our power supply systems round the clock in HK Electric

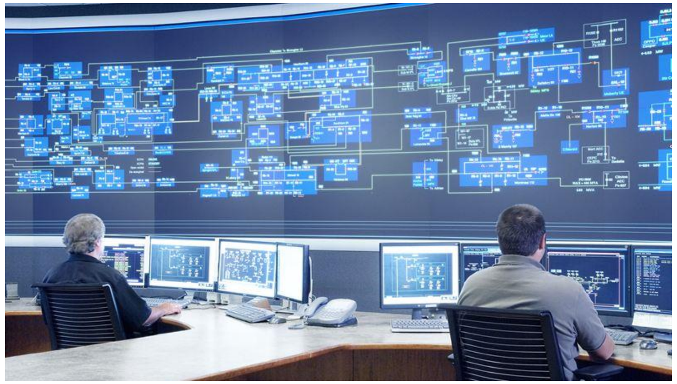
System Control Centre at CLP

SCADA: Information systems for power grids

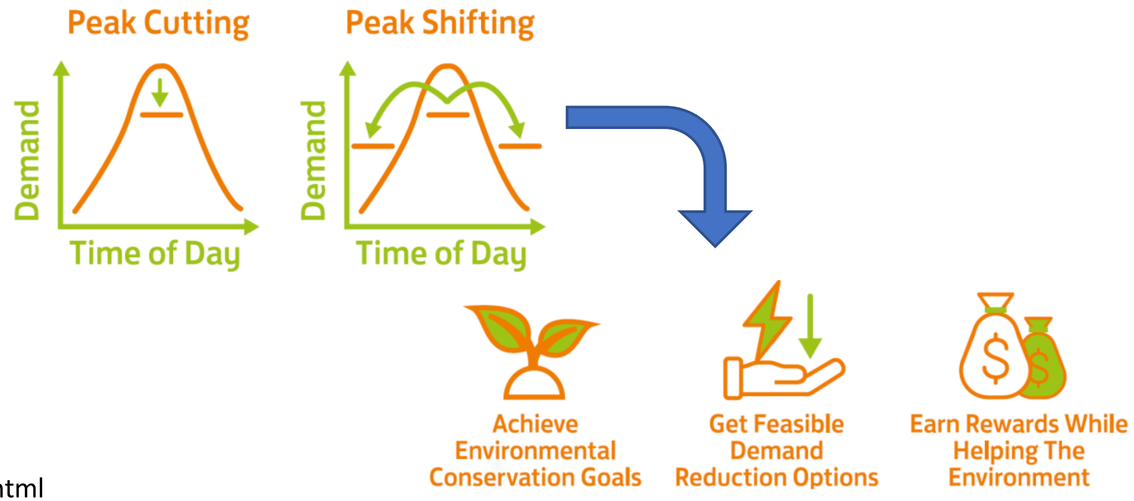
- A Supervisory Control and Data Acquisition (SCADA) system serves for data acquisition, monitor and control systems on a wide-area power system



OpenControl SCADA Network Architecture



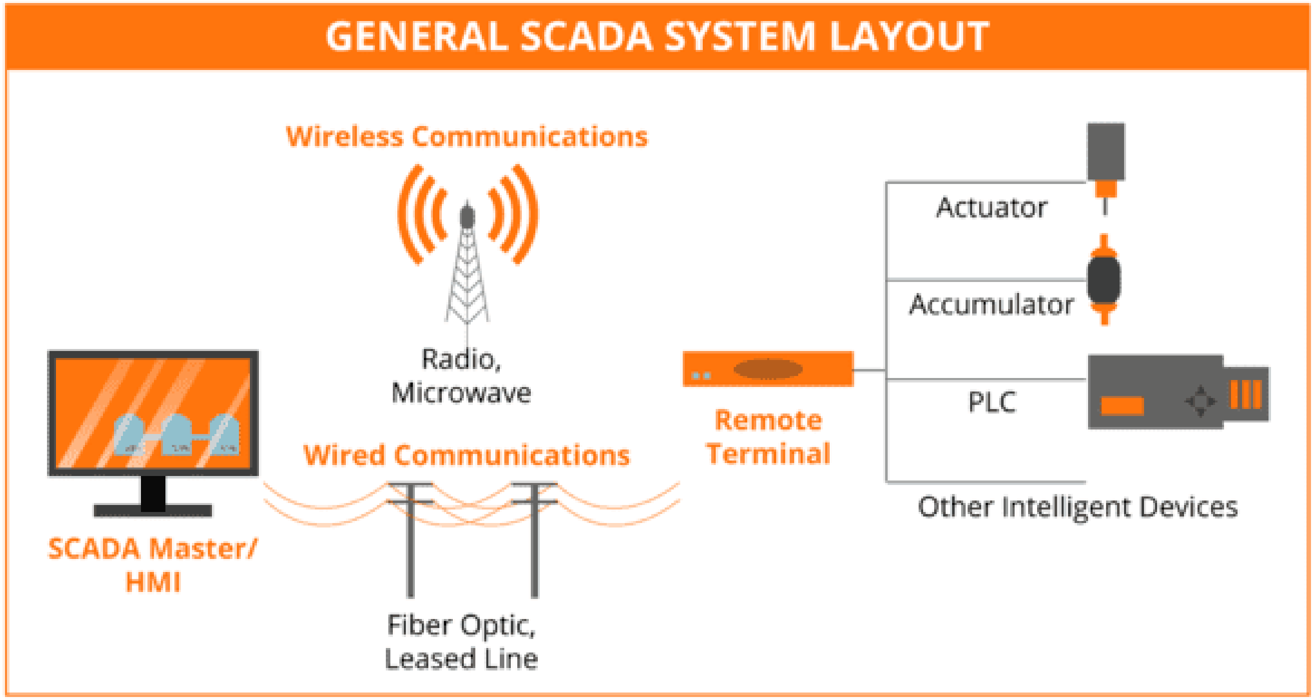
- Example of application: peak demand management



Materials source www.electricaltechnology.org/2015/09/scada-systems-for-electrical-distribution.html

Components of typical SCADA system

- Remote Terminal Units (RTUs)
  - real-time **programmable logic controllers (PLCs)** for transmitting sensing and controlling signals
- Master Terminal Units (MTUs)
  - **central host servers** to perform data processing and decision-making
- Communications System
  - to transfer data among central host data servers and the field data interface devices & control units troughing **cables, radio satellite, etc.**
- Operator Workstations
  - **computer terminals** consisting of standard HMI (Human Machine Interface) software for operator to monitor and control the remote field parameters.



Main sources: https://www.electricaltechnology.org/2015/09/scada-systems-for-electrical-distribution.html

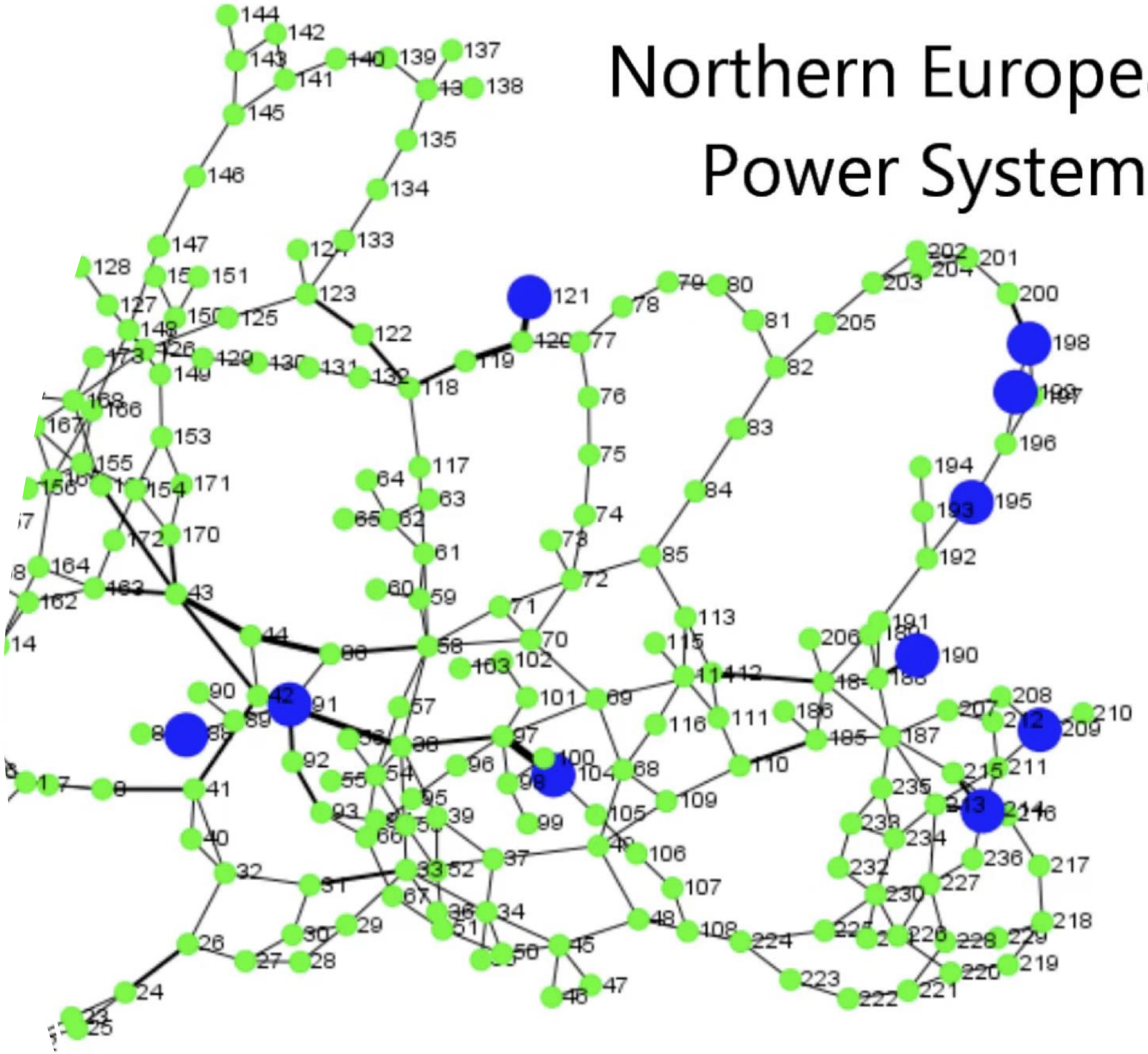
Threats to power systems

- Failures
- Attacks
  - Cyberattacks
- Evolution that changes the characteristics
  - Power electronics penetration

Cascading failure

One failure event triggers a series of failures leading to large scale blackout

Northern European Power System



Blackouts

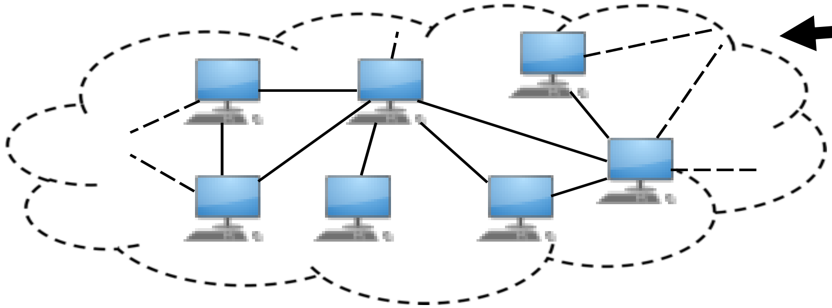
Major reasons: extreme weather, apparatus aging, human maloperation, software bug in the alarm system, cyber-attack, high penetration of power electronics…

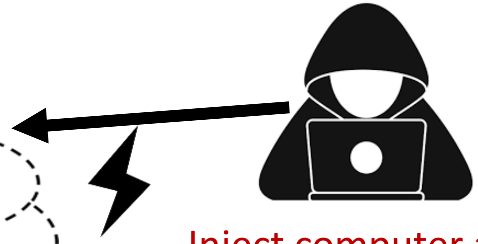
2003 USA northeast blackout

Article	People affected (millions)	Location	Date
2012 India blackouts	620	India	July 30–31, 2012
2001 India blackout	230	India	January 2, 2001
2021 Pakistan blackout	200 (90% population)	Pakistan	January 9, 2021
2014 Bangladesh blackout	150	Bangladesh	November 1, 2014
2015 Pakistan blackout	140	Pakistan	January 26, 2015
2019 Java blackout	120	Indonesia	August 4–5, 2019
2005 Java–Bali blackout	100	Indonesia	August 18, 2005
1999 Southern Brazil blackout	97	Brazil	March 11–June 22, 1999
2015 Turkey blackout	70	Turkey	March 31, 2015
2009 Brazil and Paraguay blackout	60	Brazil, Paraguay	November 10–20, 2009

Cyberattack can lead to cascading failure

Cyber network

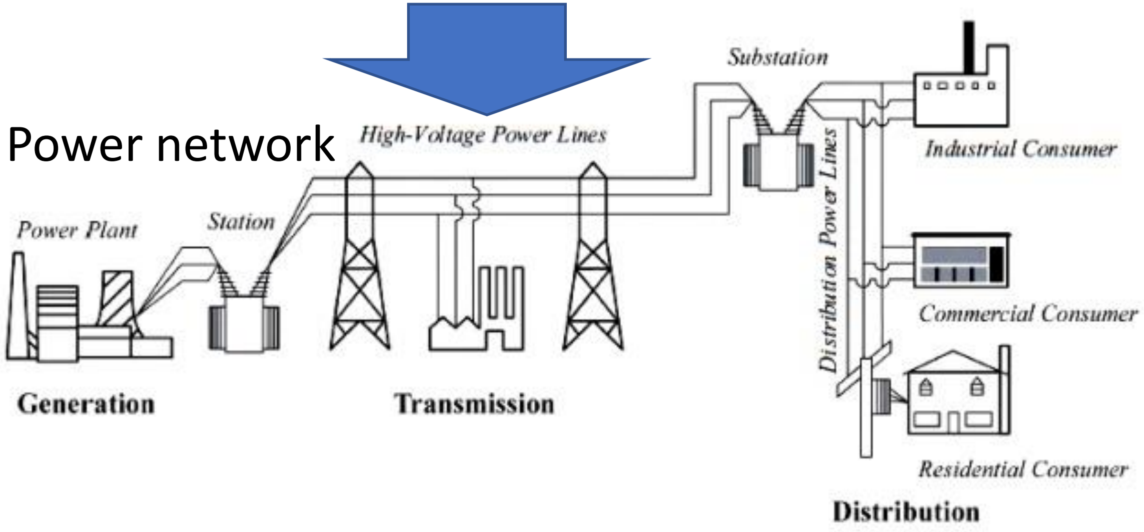




Inject computer and remotely switching substations off, and destroying IT components

Controlling and monitoring

Power network

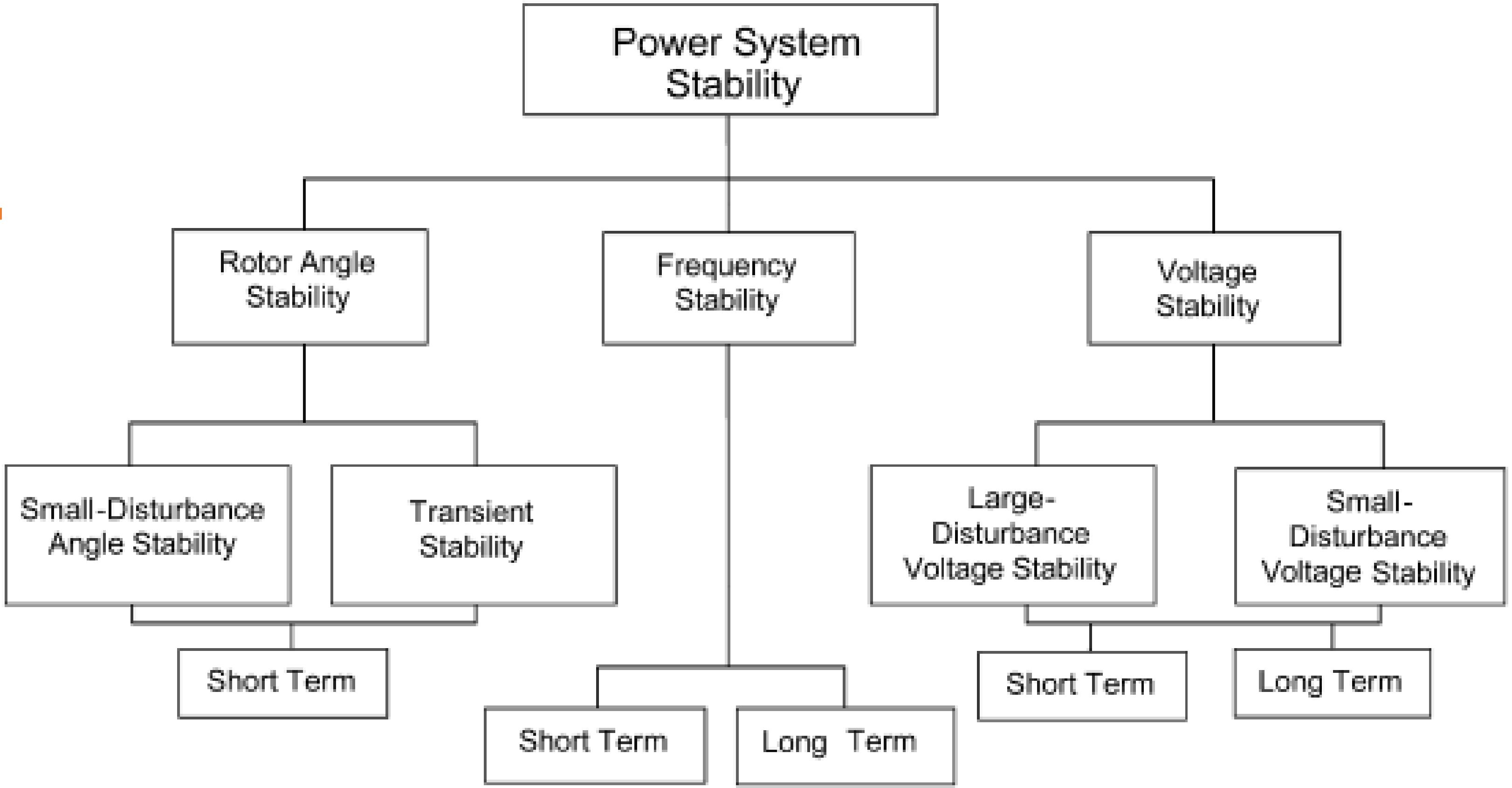


2015 Ukraine blackouts caused by cyberattack

2019 Venezuelan blackouts caused by cyberattack

How to make power safe?

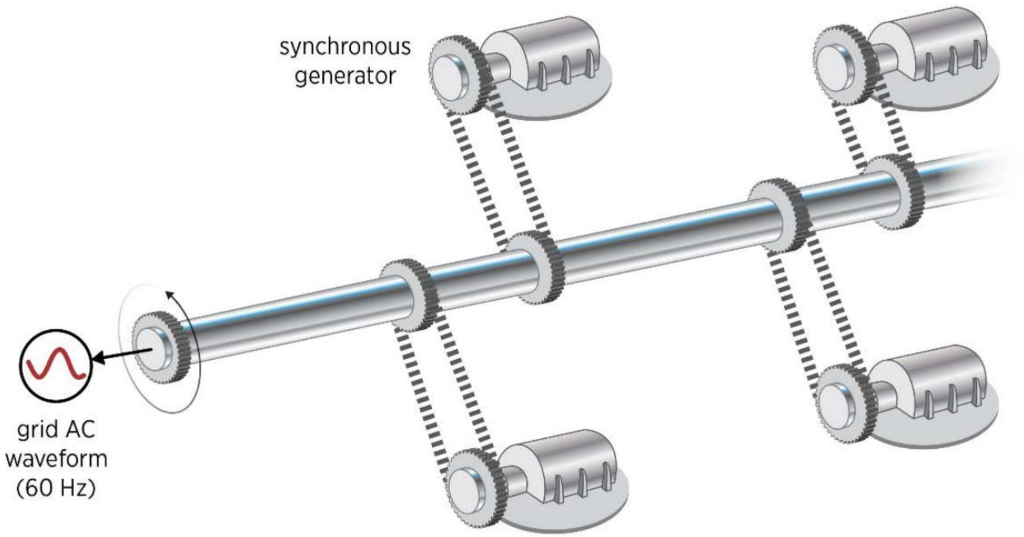
Traditional classification of power system stability and power system protection components

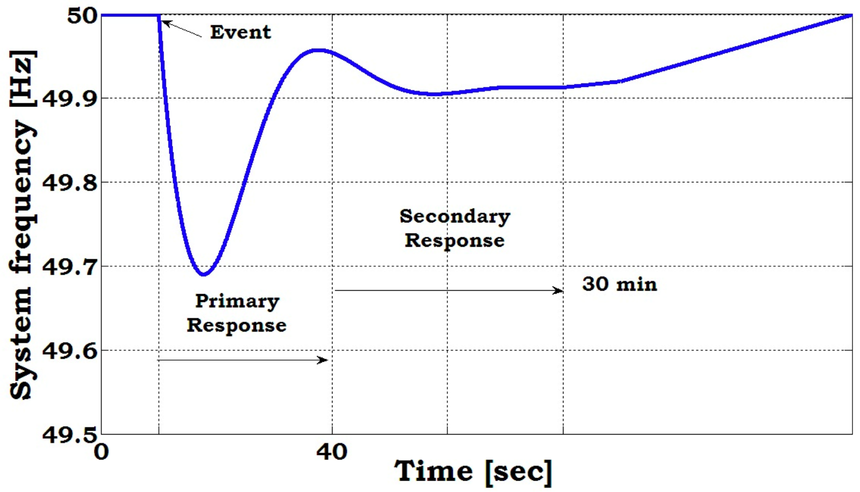


P. Kundur *et al.*, "Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions," in *IEEE Transactions on Power Systems*, vol. 19, no. 3, pp. 1387-1401, Aug. 2004, doi: 10.1109/TPWRS.2004.825981.

Synchronous generator and self regulation

- Synchronous generators (with strong inertia) working together in an electrical grid at an equilibrium point





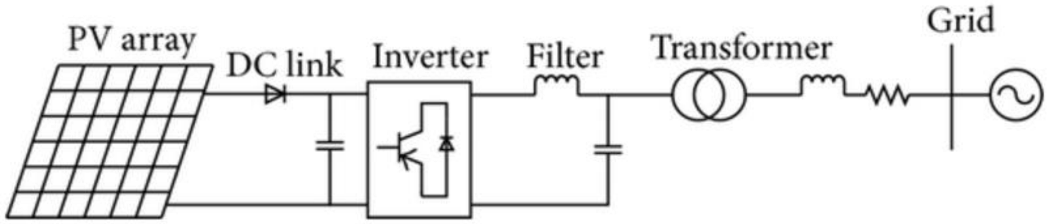
Events that disturb this balance can change the frequency, triggering the control to restore it

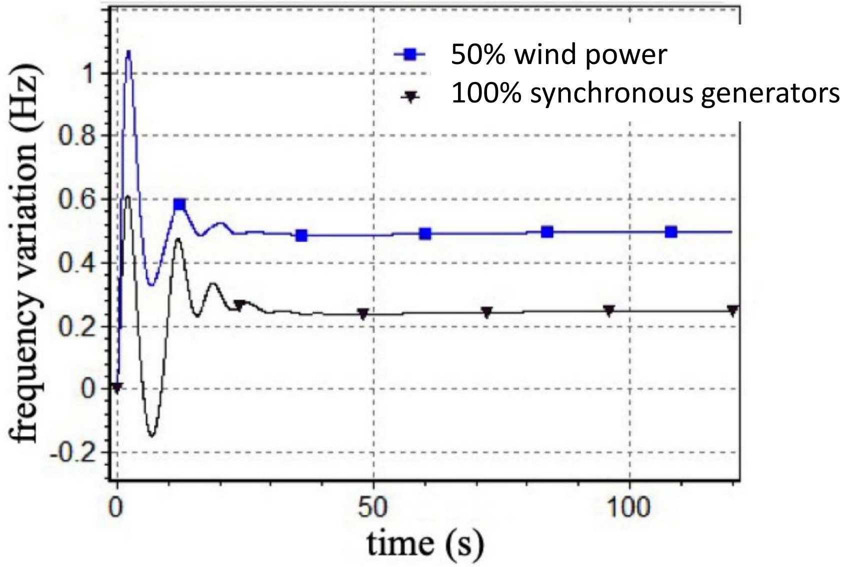
Picture source: www.nrel.gov/docs/fy20osti/73856.pdf

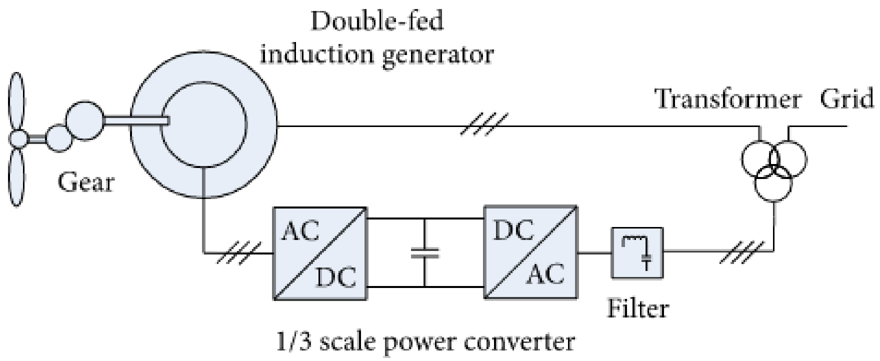
Synchronous generator and renewable energy source

Weakness of power grids with more power electronics

- Lower system inertia
- Weak frequency control
- High risk to intensify power outage





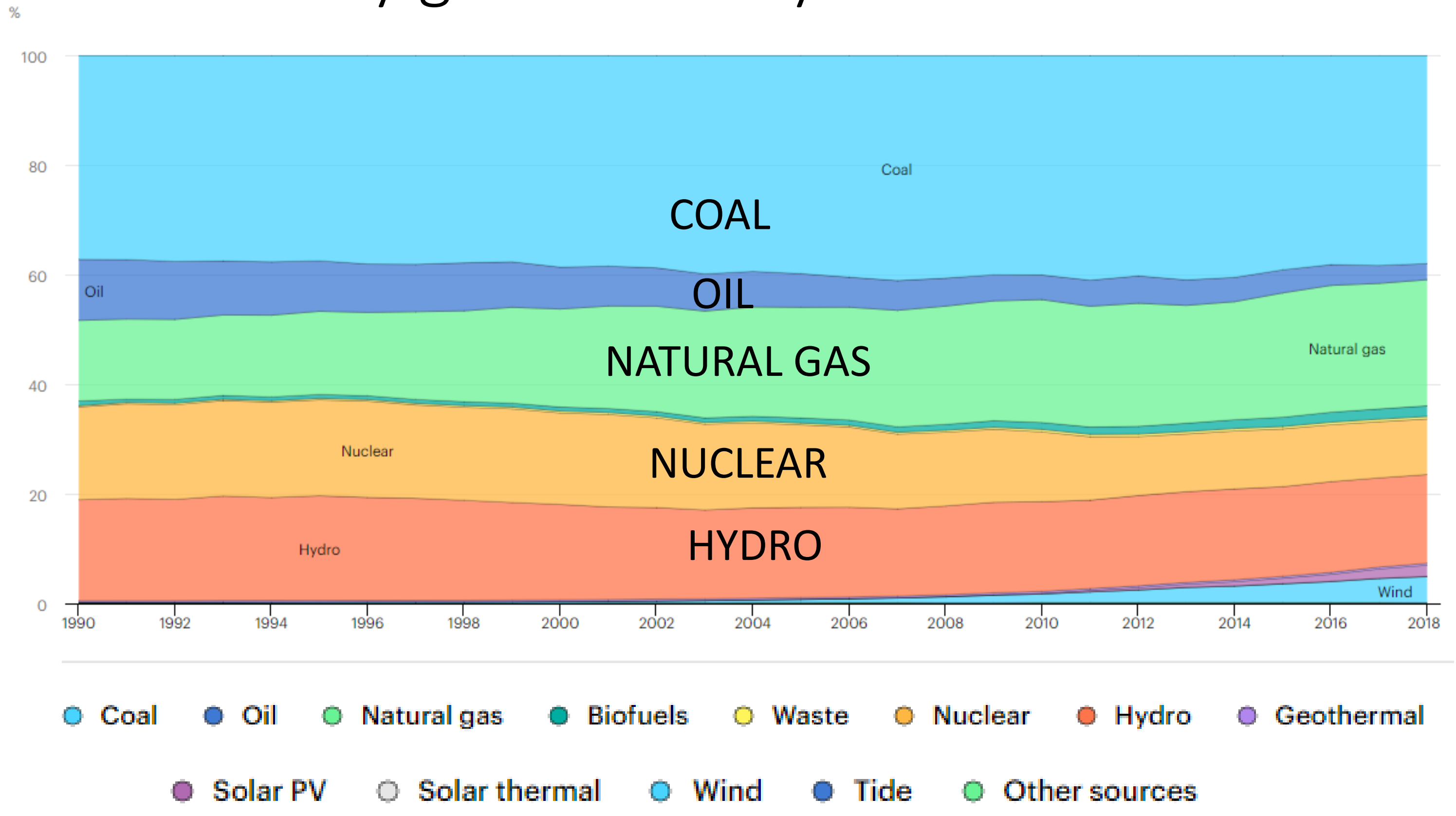


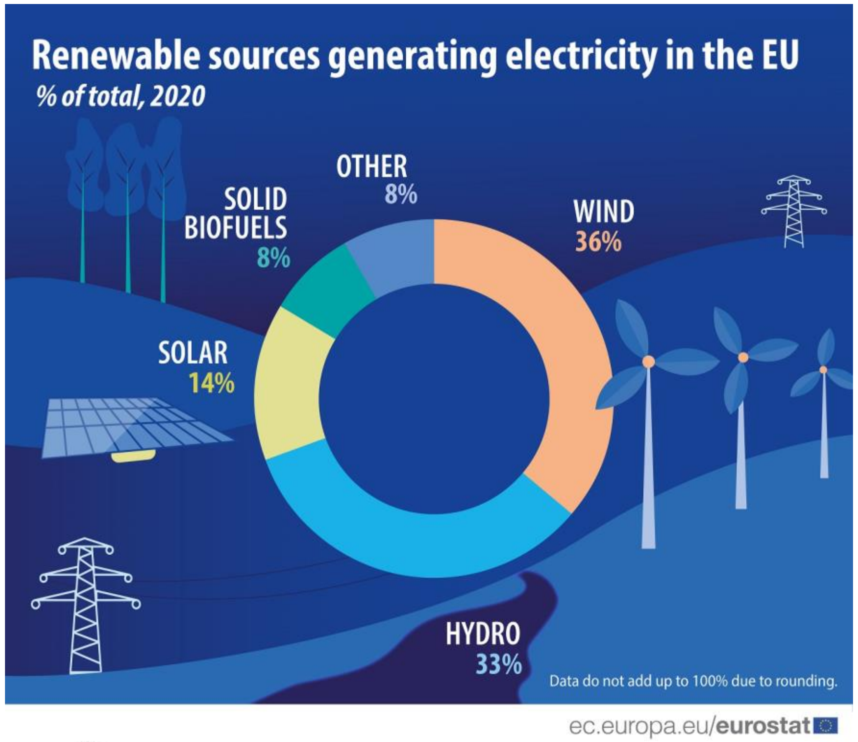
Frequency deviation response after a disturbance occurs in a power system with 100% synchronous generators (black triangle) and with 50% wind power (blue square).

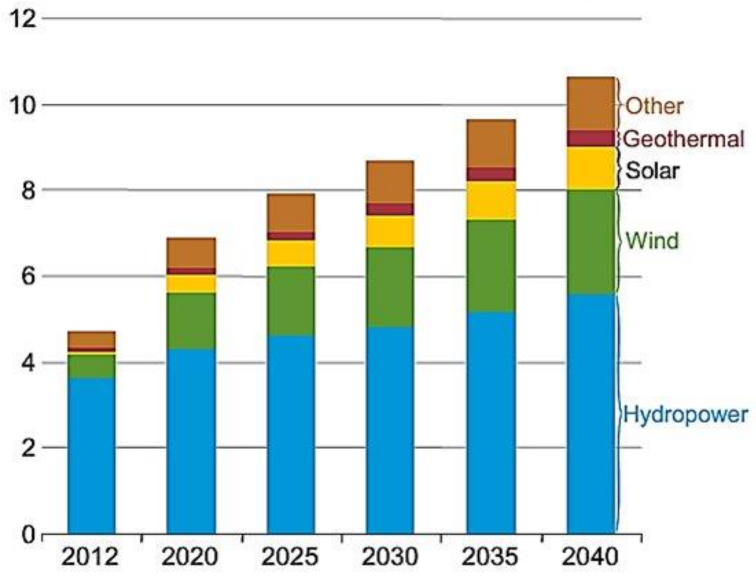
C. K. Tse et al., "Circuits and Systems Issues in Power Electronics Penetrated Power Grid," in *IEEE Open Journal of Circuits and Systems*, vol. 1, pp. 140-156, 2020, doi: 10.1109/OJCAS.2020.3020633.

Global energy supply trends

Electricity generation by sources 1990-2018







World net electricity generation from renewable energy

What is renewable energy? --- SOLAR ENERGY; WIND ENERGY; GEOTHERMAL ENERGY; HYDROPOWER; OCEAN ENERGY; BIOENERGY

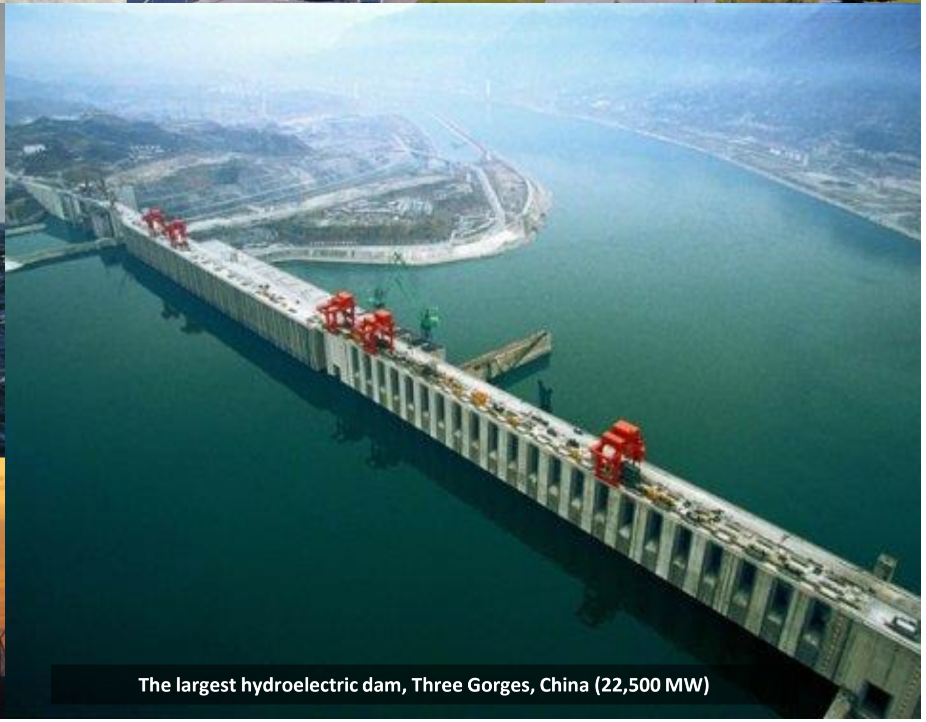
Data source: https://www.iea.org/fuels-and-technologies/electricity

The largest renewable energy projects in the world


The Largest solar PV plant, USA (550 MW, 9 billion solar panels)

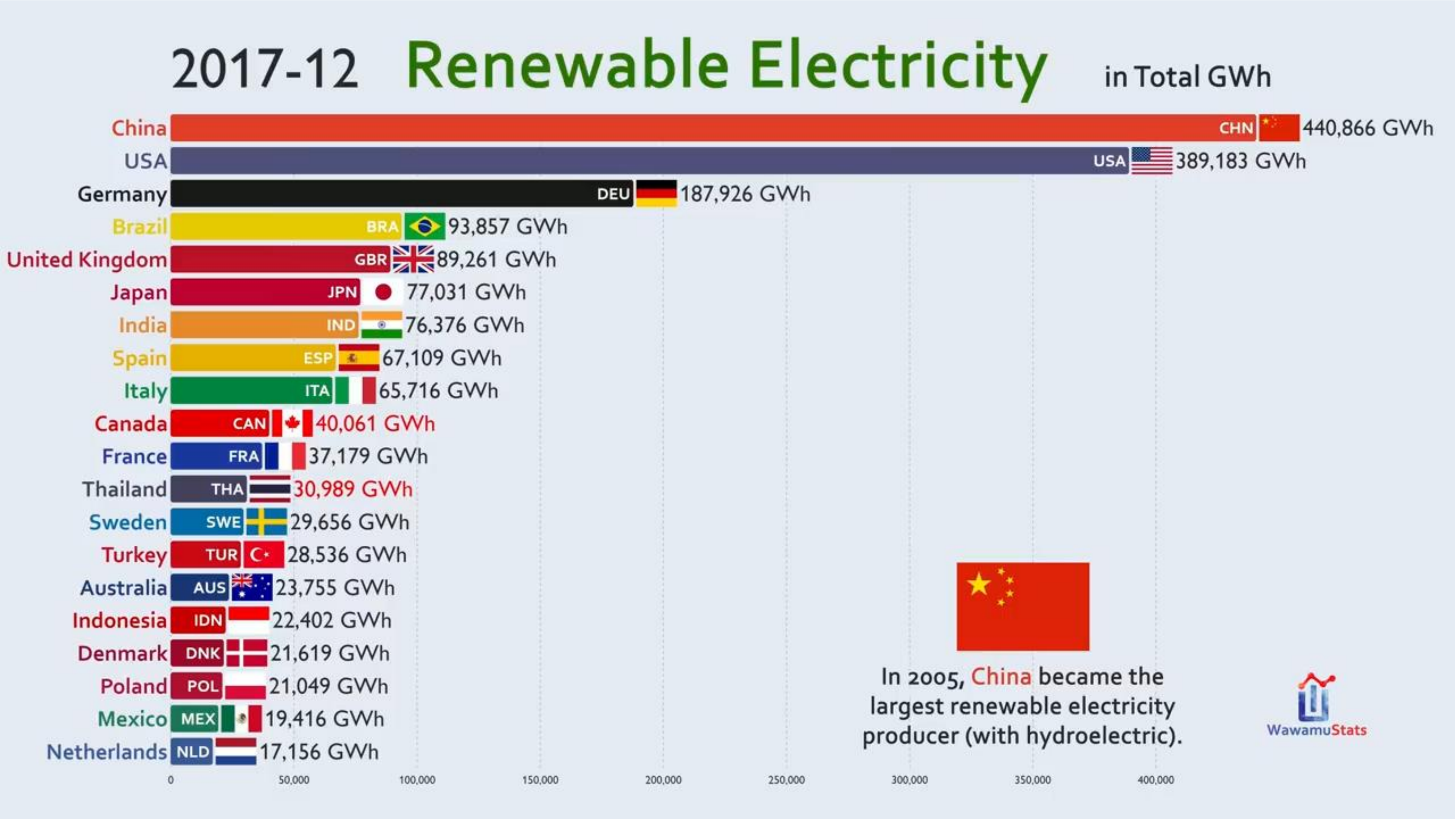

The largest biomass plant, Finland (950 MW)


The largest wave power plant, Portugal (2.25 MW)


The largest hydroelectric dam, Three Gorges, China (22,500 MW)


The largest wind farm, Gansu, China (6,000 MW)

Top 20 Country by Renewable Electricity Production (1960-2018)

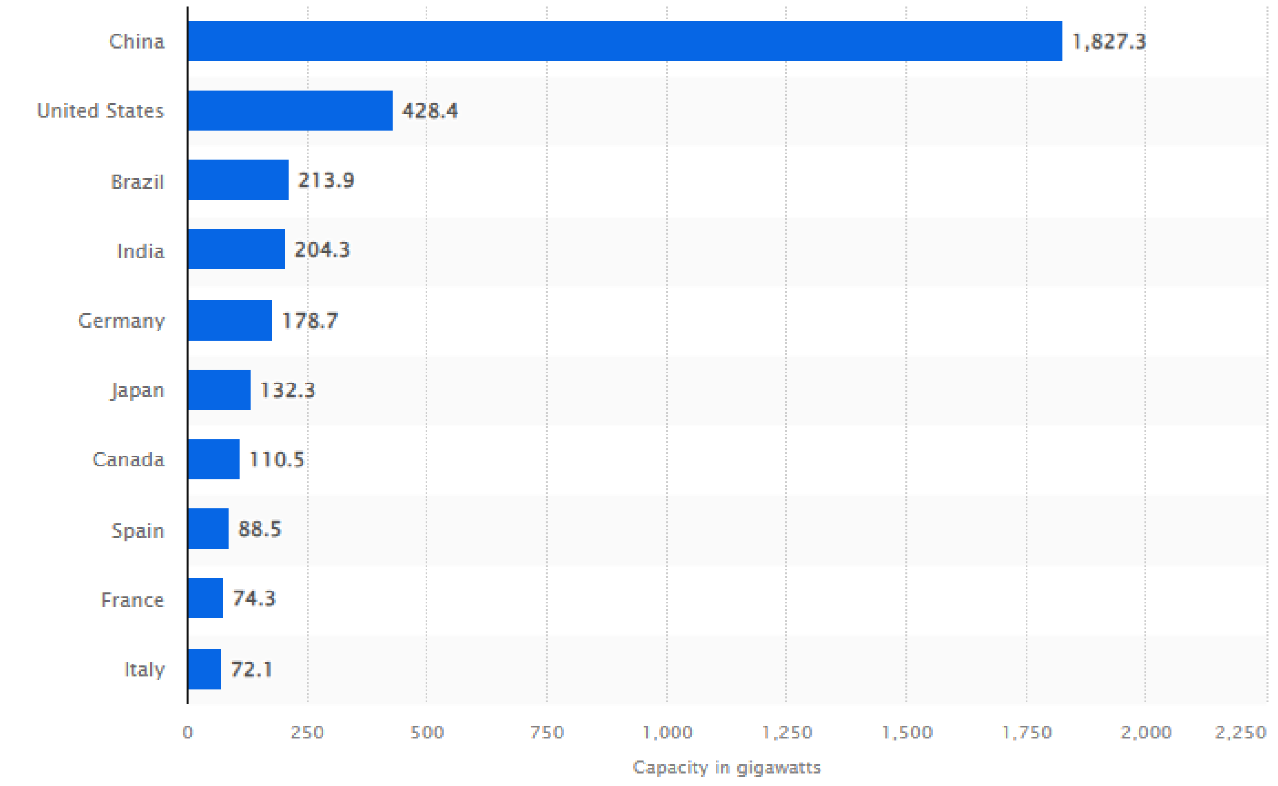


https://www.youtube.com/watch?v=rugrDueew1Q&ab_channel=WawamuStats

Installed renewable energy capacity worldwide in 2024

Leading countries in installed renewable energy capacity worldwide in 2024

(in gigawatts)



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https://www.youtube.com/watch?v=rugrDueew1Q&ab_channel=WawamuStats

Some References

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3. J. D. Glover, T. J. Overbye, and M. S. Sarma, Power System Analysis & Design, Sixth Edition, Cengage Learning, 2017.
4. C. K. Tse, Linear Circuit Analysis, London: Addison-Wesley, 1998.