Electrical Power Distribution

Week 1

Course Contents

These are the "main and big headlines" for the topics we will study

- Introduction to electrical distribution system
- Distribution system elements & configurations
- Electrical load characteristics
- Voltage regulation in distribution system
- Distribution transformers
- Reactive power control in distribution system
- Operation and control of distribution system

What will I learn from this course??

- Increase awareness of power system topics especially in the field of MV-LV networks
- Understand and engage in a life long learning environment and realize the need to motivate and teach self
- Ability to read and understand technical papers, guidelines and standards
- Understand the importance of engineering ethics and standards in all work aspects
- Being able to judge, comment, negotiate in a team environment

UPGRADE YOURSELF, READ MORE, LEARN MORE

How will you be graded and assessed?

- **RULE 1:** WORK AND READ A LOT! EVERY WEEK YOU HAVE AN ASSIGNMENT!
- **RULE 2:** BE ON TIME IN ASSIGNMENTS, NO EXCUSES FOR LATE OR UN-HANDED ONES. IF YOU MISS IT, YOU CANT MAKE IT UP!
- **RULE 3:** BE ON TIME! I DON'T LIKE LATE ENTRIES
- **RULE 4:** LEAVE THE REST FOR ME

System voltage classes according to IEEE Std 141-1993

- **Low voltage:**

A class of nominal system voltages less than 1000 V.

- **Medium voltage:**

A class of nominal system voltages equal to or greater than 1000 V and less than 100 000 V.

- **High voltage:**

A class of nominal system voltages equal from 100 000 V to 230 000 V.

System voltage classes according to IEC Standard no. 38 (International Electro technical Committee)

- **Low voltage (LV)**

  For a phase-to-phase voltage between 100 V and 1000 V. The standard ratings are: 400 V - 690 V - 1000 V (at 50 Hz)

- **Medium voltage (MV)**

  For a phase-to-phase voltage between 1000 V and 35 kV. The standard ratings are: 3.3 kV - 6.6 kV - **11 kV** - 22 kV - 33 kV

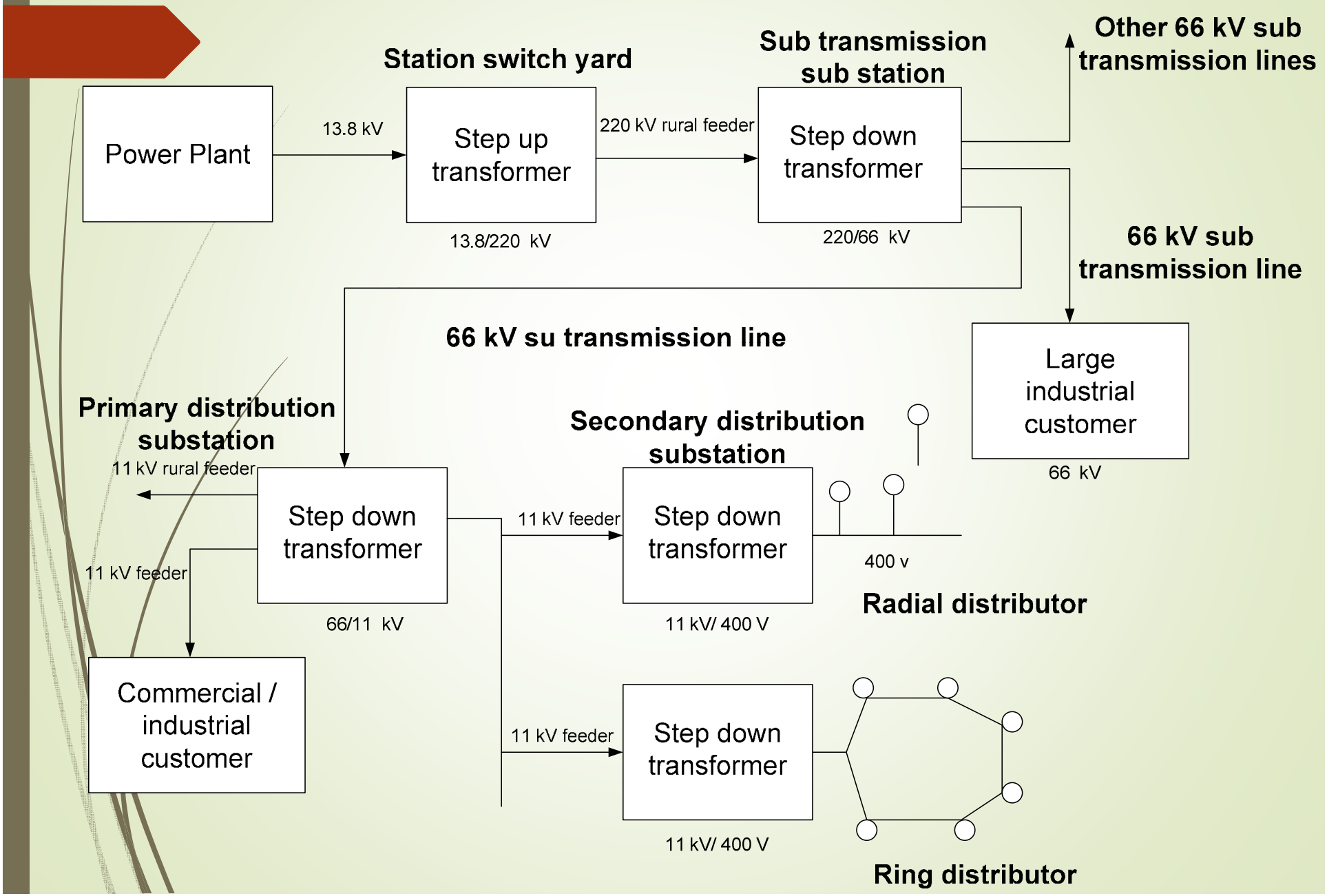
- **High voltage (HV)**

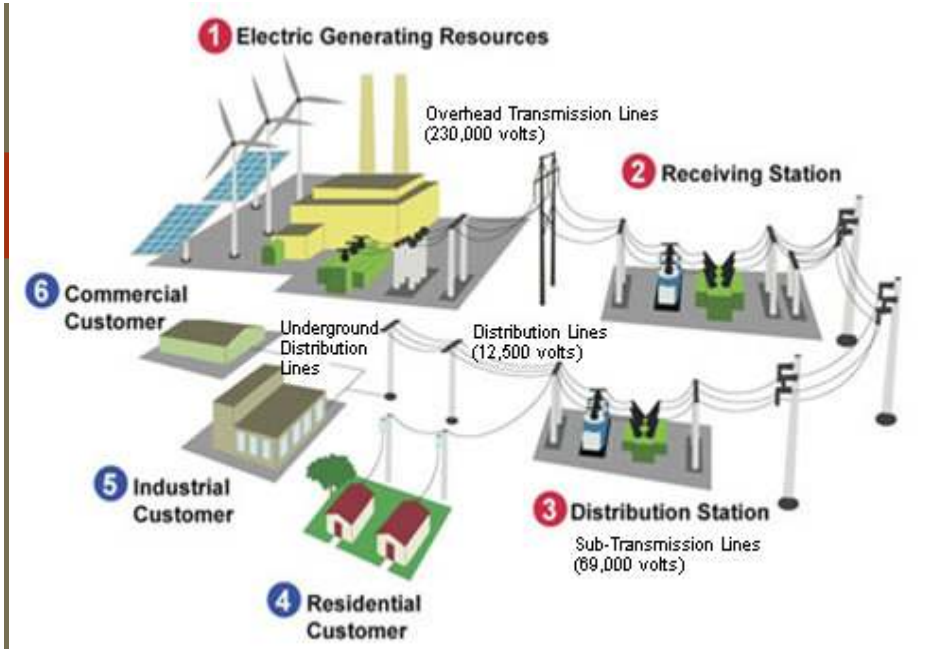
  For a phase-to-phase voltage between 35 kV and 230 kV. The standard ratings are: 45 kV - **66 kV** - 110 kV - 132 kV - 150 kV - 220 kV.

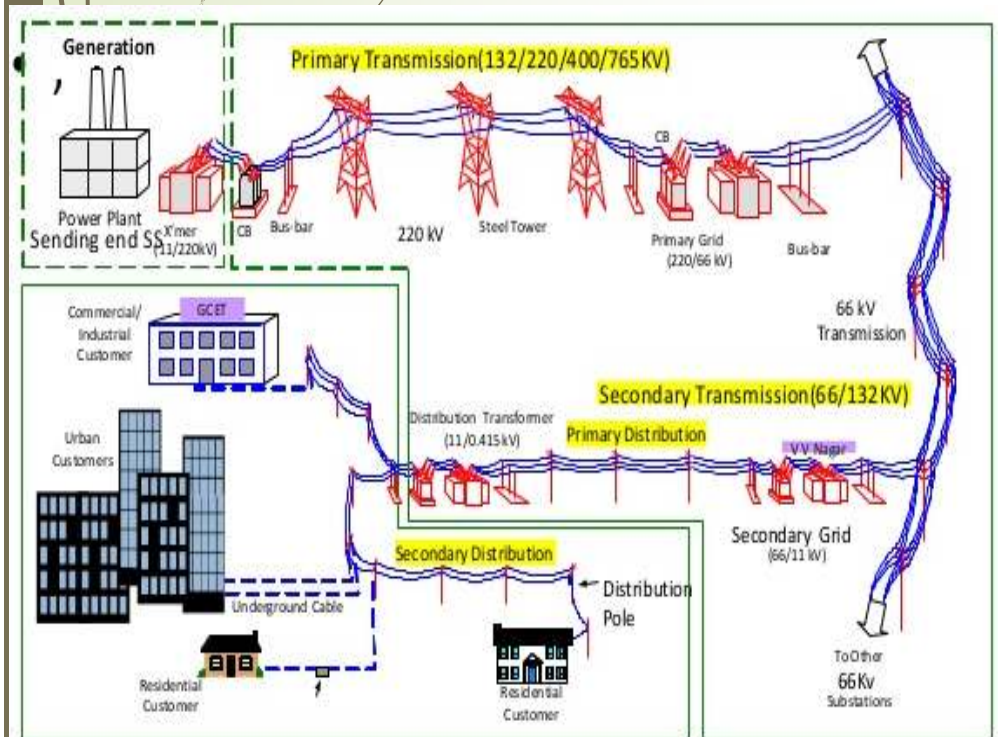
66 kV= High voltage in Egypt
11-22 kV= Medium voltage in Egypt

الكود المصري مستوحي من IEC

Substation and Distribution system







Sub-transmission *lines* carry large amounts of power from the bulk power substations **to the *main distribution*** *substations* within the immediate area of use at intermediate voltages. The *medium voltage network* carries electrical power **from the main distribution substation**s either **directly to large industrial and commercial consumers or to distributor centers within residential areas at medium voltages**. **The primary feeders carry the electrical power from distributer centers to step down distribution transformers**. The three-phase 380 V four-wire secondary cable carries the electrical power from the distribution transformer to building main switchboard.

Generating Station:

The place where electric power produced by parallel connected three phase alternators/generators is called Generating Station. The Ordinary generating voltage may be 11kV, 11.5 kV 12kV or 13kV. But economically, it is good to step up the produced voltage to 132kV, 220kV or 500kV or greater by Step up transformer (power Transformer).

Primary Transmission:

The electric supply (in 132kV, 220 kV, 500kV or greater) is transmit to load center by overhead transmission system.

Secondary transmission:

Area far from city which have connected with receiving station by line is called Secondary transmission. At receiving station, the level of voltage reduced by step-down transformers up to 132kV, 66 or 33 kV, and Electric power is transmit by three phase three wire overhead system to different sub stations.

Primary Distribution:

At a sub station, the level of secondary transmission voltage (132kV, 66 or 33 kV) reduced to 11kV by step down transforms. Generally, electric supply is given to those heavy consumer whose demand is 11 kV, from these lines which caries 11 kV and a separate sub station exists to control and utilize this power. For heavier consumer (at large scale) their demand is about 132 kV or 33 kV, they take electric supply from secondary transmission or primary distribution (in 132 kV, 66kV or 33kV) and then step down the level of voltage by step-down transformers in their own sub station for utilization (i.e. for electric traction etc).

Secondary Distribution:

Electric power is given by (from **Primary distribution line i.e.11kV**) to distribution sub station. This sub station is located near by consumers areas where the level of voltage reduced by step down transformers 440V by Step down transformers. These transformers called Distribution transformers, three phase four wire system). So there is 400 Volts (Three Phase Supply System) between any two phases and 230 Volts (Single Phase Supply) between a neutral and phase (live) wires. Residential load (i.e. Fans, Lights, and TV etc) may be connected between any one phase and neutral wires, while three phase load may be connected directly to the three phase lines.

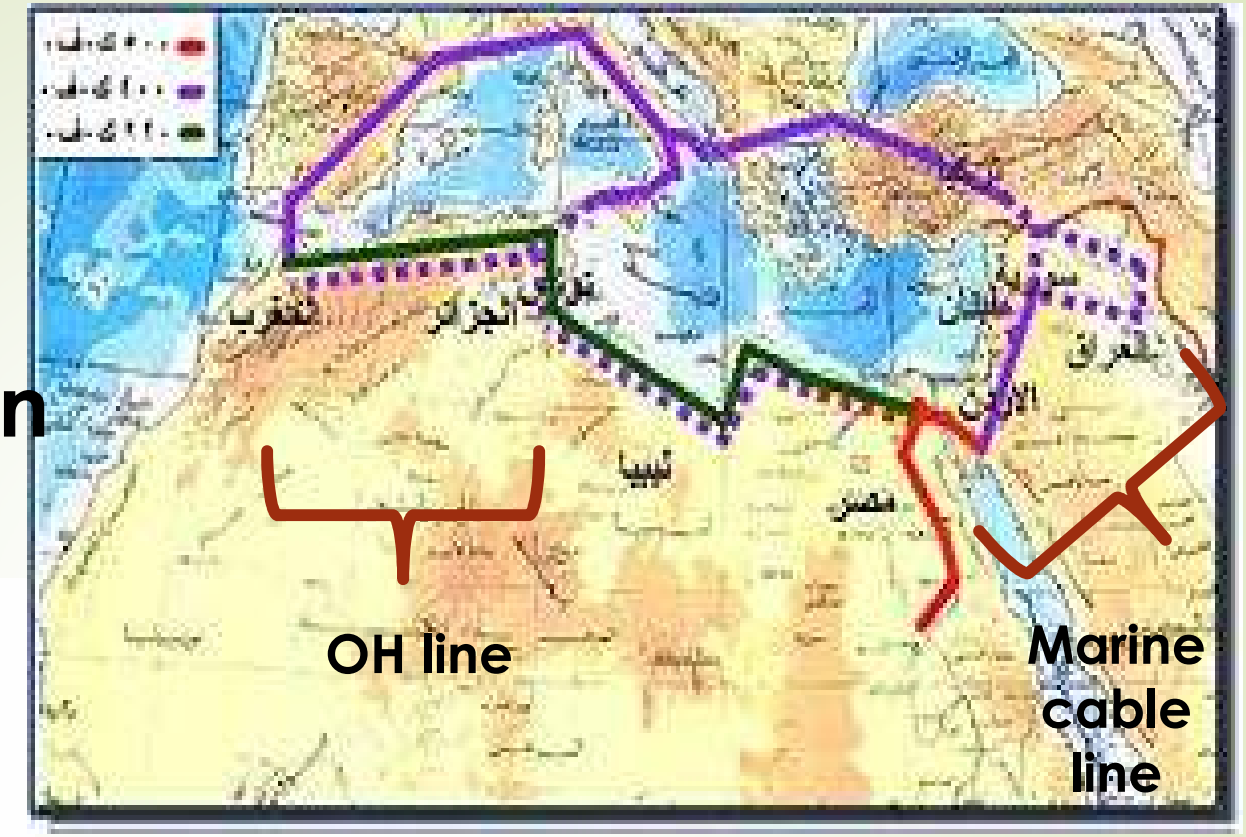
Egyptian Network

Generation : 24- 30 kV محطات التوليد

Transmission : محطات الرفع لأغراض النقل علي أكثر من مستوي

- 132 kV : جنوب الصعيد لربط الصعيد كله
- 220 kV: معظم الجمهوريه (شرق الدلتا – غرب الدلتا- القاهرة الكبري- وجه بحري- حدود مصر- سيناء)
- 500 kV: خط رابط بين أسوان و القاهرة طوله تقريبا 950 كم

Egyptian Grid Interconnection



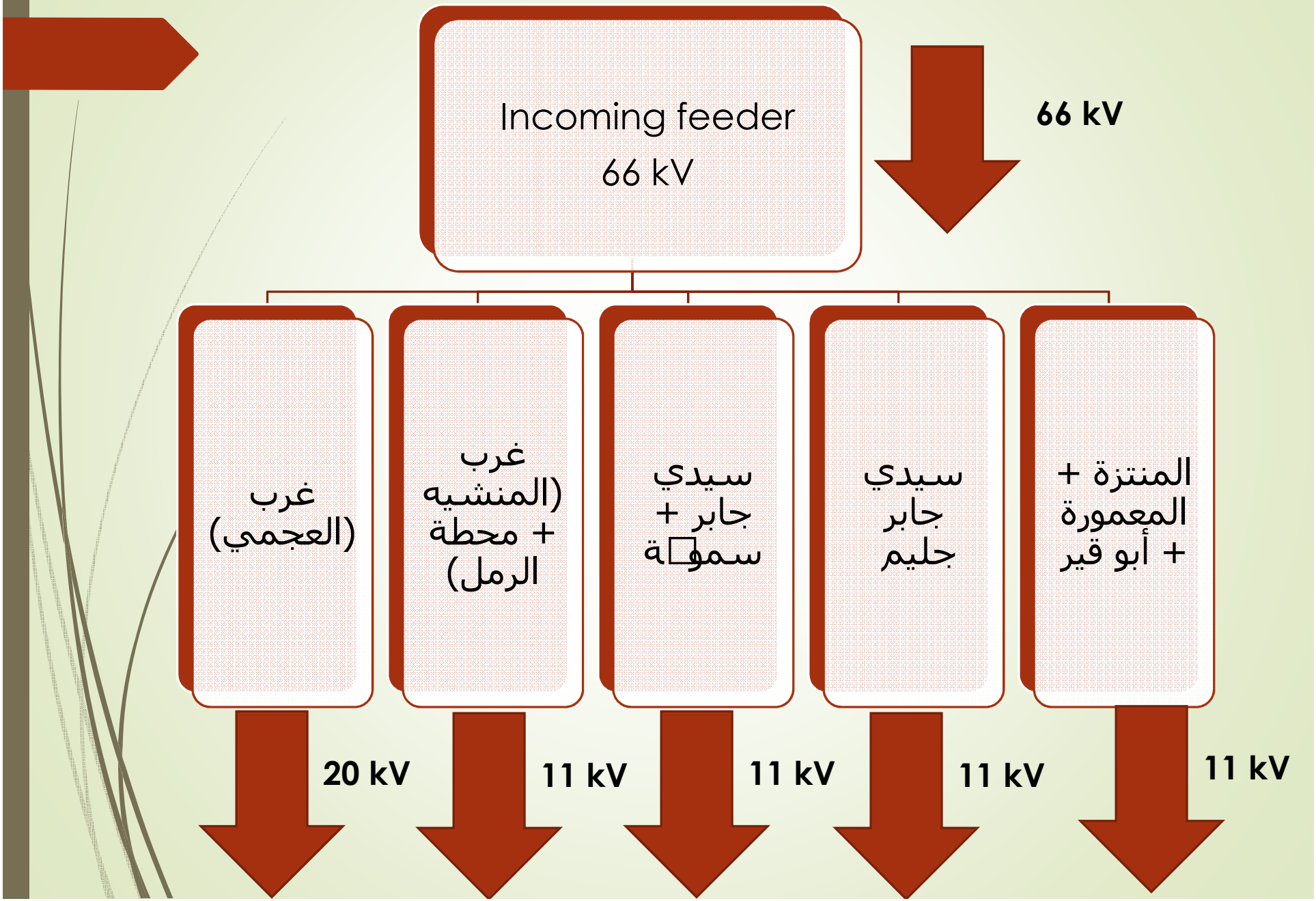
البيان	خط الربط المصري الليبي	خط الربط المصري الاردني		
جهد الربط (ك.ف)	220	400		
دول الربط	ليبيا	الاردن	سوريا	لبنان
الطاقة المباعة (صادرة) (ج.و.س)	100	1277	220	82
الطاقة الواردة (ج.و.س)	64	26	2	-

Egyptian Grid Useful Statistics

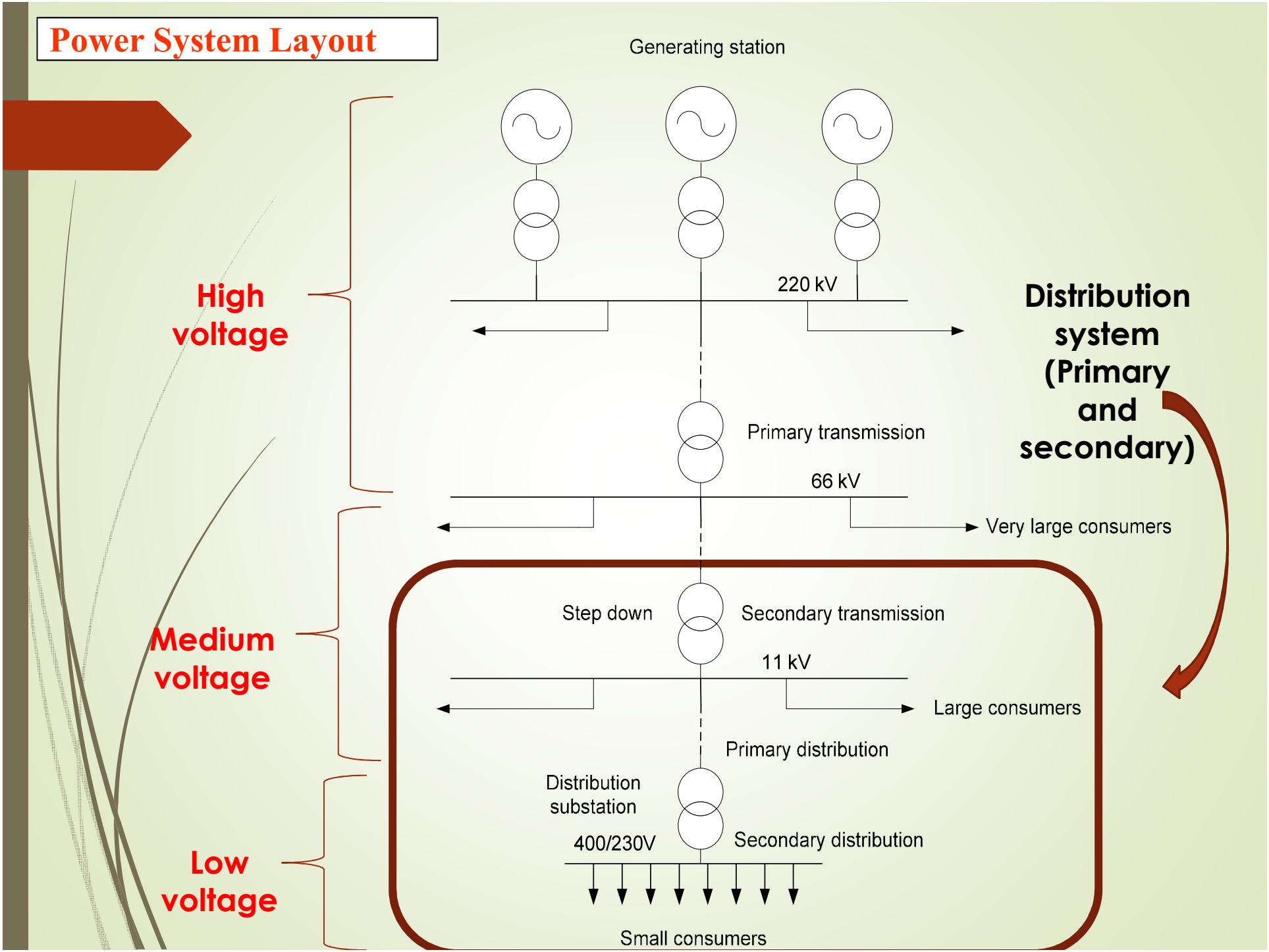
البيان	%إجمالي الطاقة الكهربية المنتجة
الطاقة المائية	7.94
طاقة الرياح	0.79
الطاقة الشمسية	0.07
كهرباء مولدة من المحطات الحرارية المربوطة بالشبكة	91.02
كهرباء مولدة من المحطات الغير مربوطة بالشبكة	0.14
كهرباء مشتراة من فائض الشركات الصناعية	0.04
إجمالي (مليون ك.و.س)	**168069**

تقرير وزارة الكهرباء عم 2013-2014

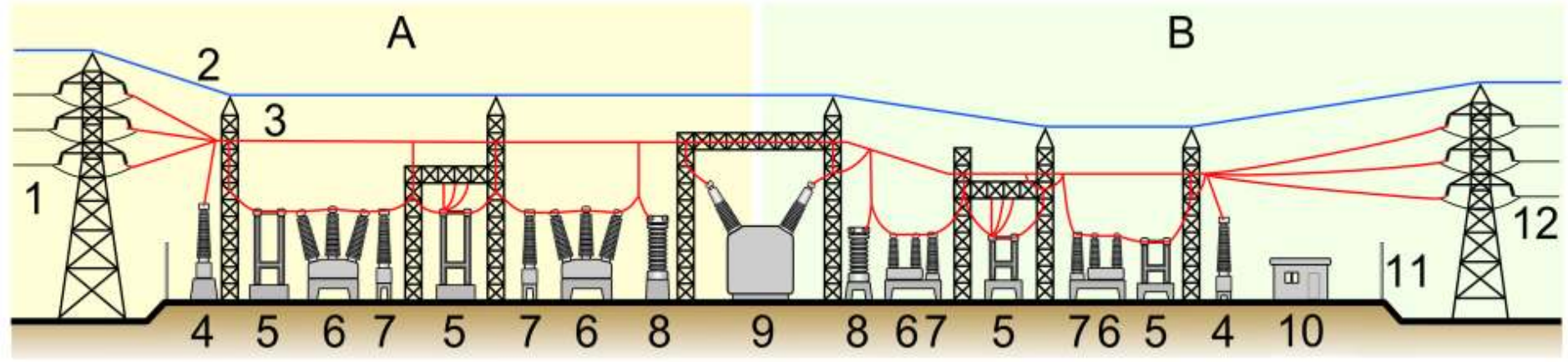
Alexandria Network (Distribution)



Power System Layout



Substation and distribution system



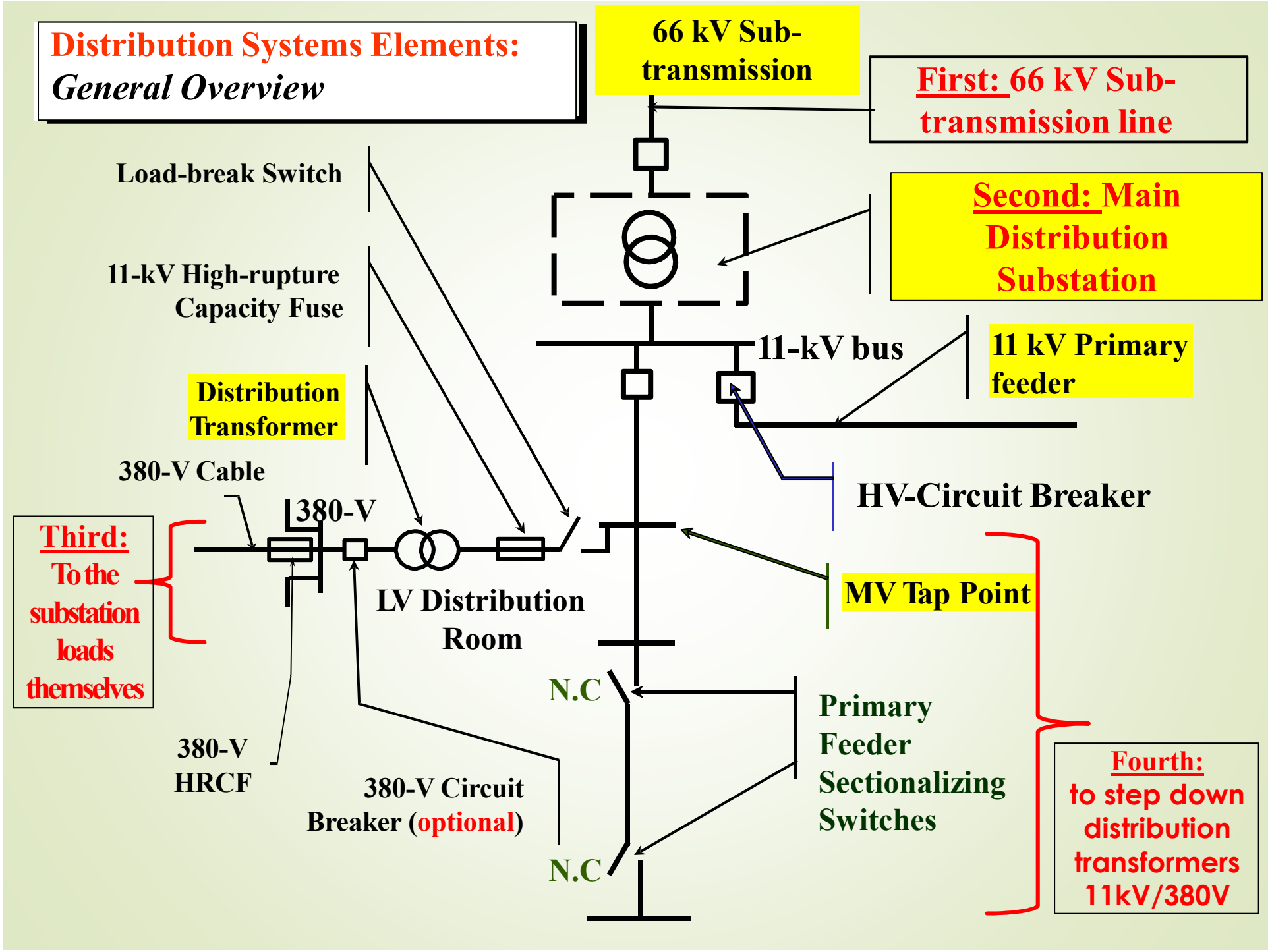
- **A:Primary power lines' side**
- **B:Secondary power lines' side**
- 1.Primary power lines
- 2.Ground wire
- 3.Overhead lines
- 4.Transformer for measurement of electric voltage
- 5.Disconnect switch
- 6.Circuit breaker
- 7.Current transformer
- 8.Lightning arrester
- 9.Main transformer
- 10.Control building
- 11.Security fence
- 12.Secondary power lines

Substation and distribution system

- **What does a substation do?**
  - Receives electricity from an incoming line at voltage level and supplies the same to outgoing lines at a reduced voltage level using a power transformer
  - Acts as connection point for local networks
  - Regulated voltage to compensate for system voltage drop by injecting reactive power to the transmission or dist. Circuits
  - Monitoring point for control centers using CTs and PTs
  - Acts as a switchyard for switching electric transmission and dist. Circuits into and out of the system using bus bards, circuit breakers and isolators.
  - Protection purposes (fuses, CBs, earthing, surge..etc)
  - Could be indoor, outdoor or pole mounted.

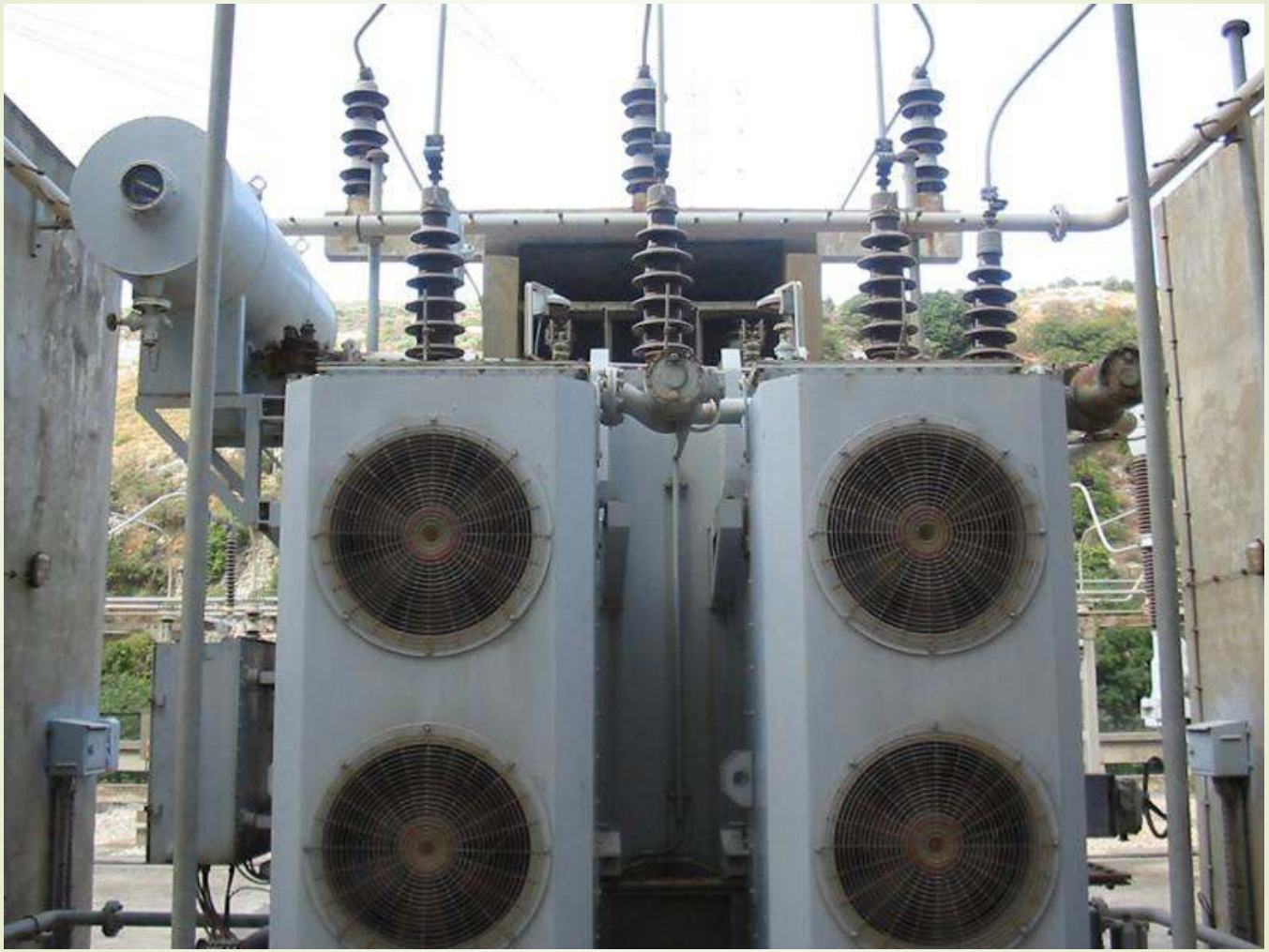
Pole mounted single phase distribution transformer

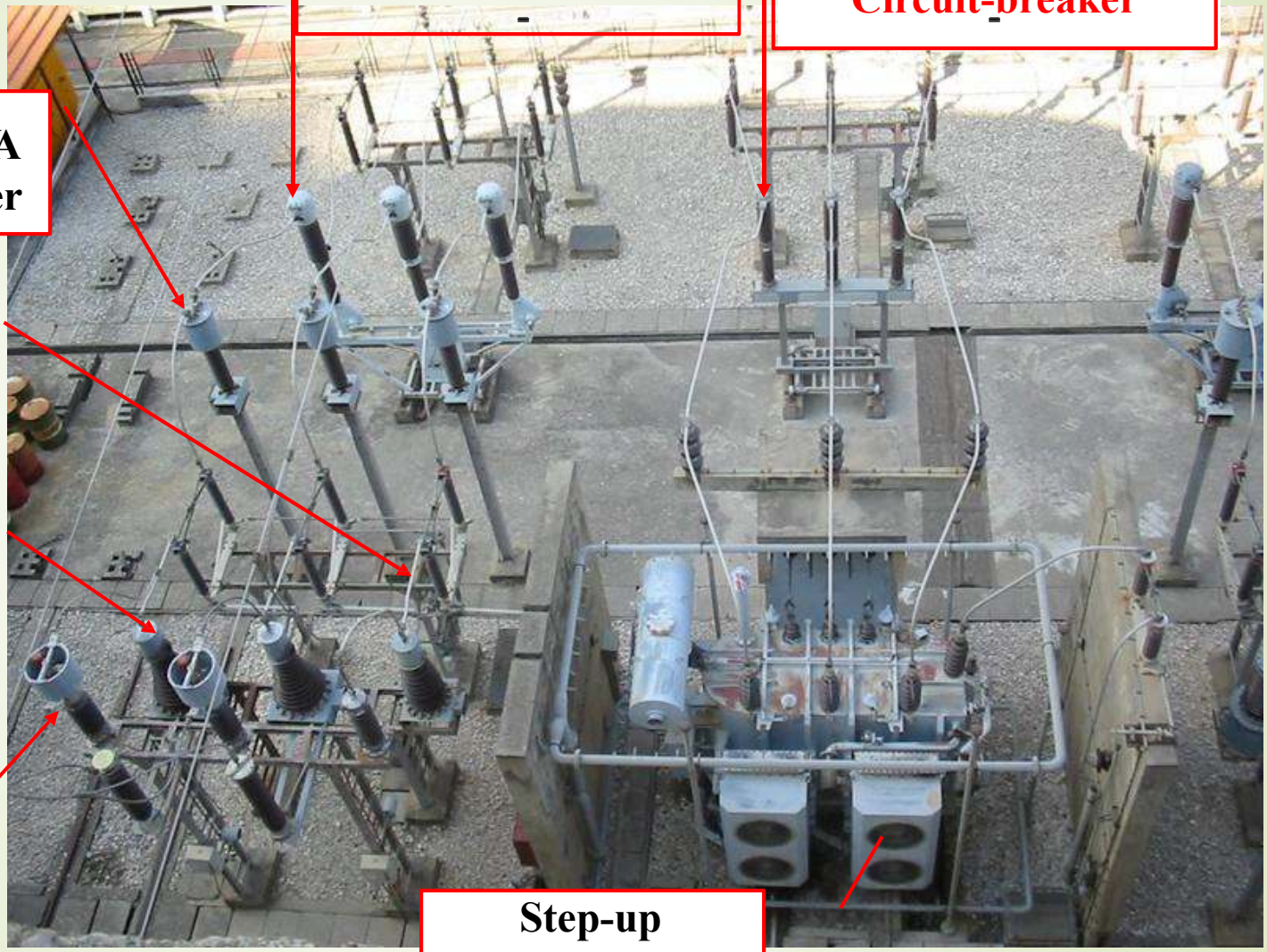
Substation power transformer


Distribution Systems Elements:
General Overview
66 kV Sub-transmission
First: 66 kV Sub-transmission line
Load-break Switch
11-kV High-rupture Capacity Fuse
Second: Main Distribution Substation
11-kV bus
11 kV Primary feeder
Distribution Transformer
380-V Cable
380-V
HV-Circuit Breaker
Third: To the substation loads themselves
LV Distribution Room
MV Tap Point
N.C
Primary Feeder Sectionalizing Switches
380-V HRCF
380-V Circuit Breaker (optional)
N.C
Fourth: to step down distribution transformers 11kV/380V

Sub- transmission line carries large amounts of power from the bulk power substations to the ***main distribution substations*** within the immediate area of use at intermediate voltages, typically 132 or 66 kV. The ***medium voltage network*** carries electrical power from the main distribution substations either directly to **large industrial and commercial consumers or to distributor centers within residential areas at medium voltages**, typically 33, 20 or 11 kV. The primary feeders carry the electrical power from distributer centers to step down distribution transformers 11kV/380V. The three-phase 380 V four-wire secondary cable carries the electrical power from the distribution transformer to building main switchboard.

Typical 11/ 71 kV, 33 MVA Step-up substation in generating power plant

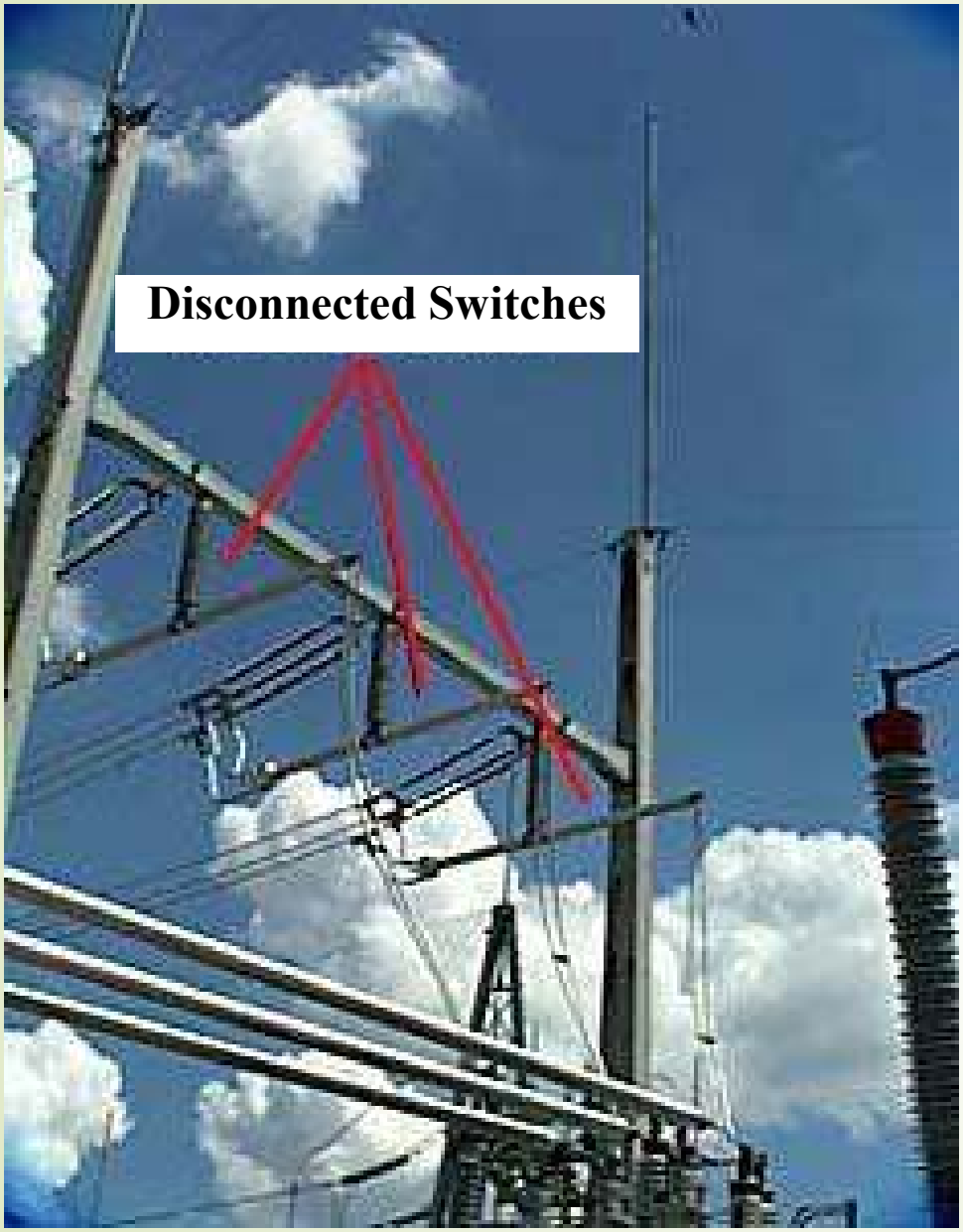



100-kV/1250-A ,
SF_6-type
Circuit-breaker
100-kV/1250-A ,
Oil-type
Circuit-breaker
80-kV/100-V , 200VA
Potential transformer
Disconnecting
Switches
300-600/5-A, 75VA
current transformer
Lightning
Arrestor
Step-up
Transformer

Three 11-kV/380-V, 125 kVA Auxiliary Transformer

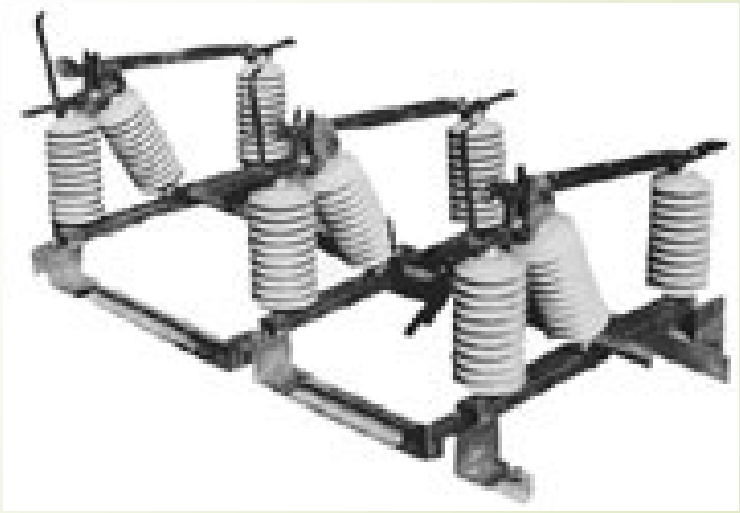
Oil-type Circuit Breakers

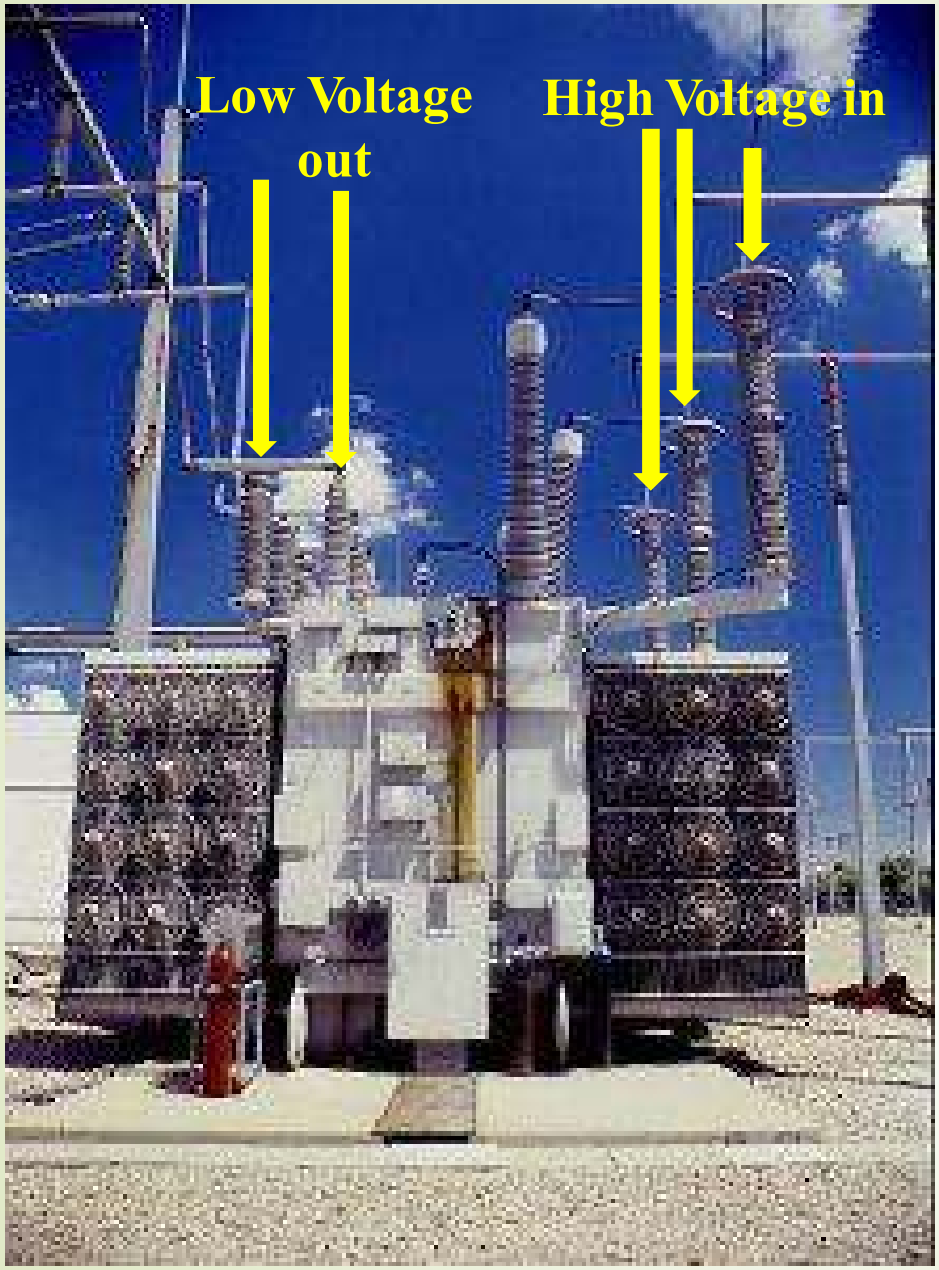
- Used to switch circuits in and out of a substation
- Oil used for:
  - Cooling medium
  - Prevent arcing



Substation Switches

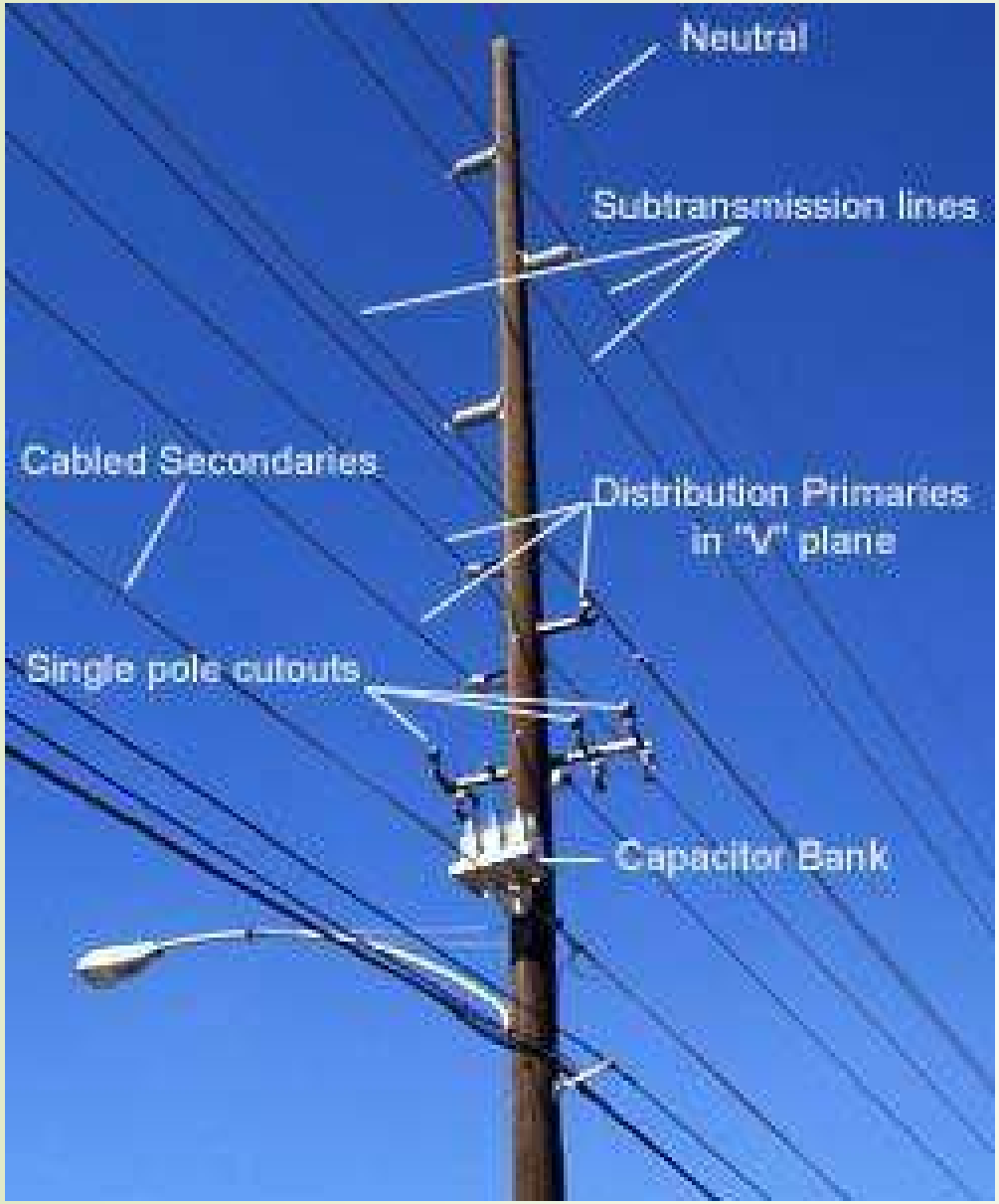
- Used to:
  - Isolate equipment
  - Redirect current





Power Transformer

- Steps down the voltage



Typical Power pole

- Carries:
  - Primary lines
  - Secondary lines
  - Phone lines
  - Cable TV
  - Ground wire

Distribution Systems Configurations: أنماط شبكات التوزيع

Primary Distribution System Arrangements

The structure of distribution system and components used depends on two factors:

- **The initial cost.**
- **Reliability.**
  - **Service continuity.**
  - **Voltage regulation.**
  - **Efficiency.**
  - **Operating and maintenance costs.**

More reliable systems mean higher installation costs which will be translated into higher price for kWh consumption

The choice between reliability and cost depends on the infra structure

example: Milling factories
Furnaces and steel
residential area
commercial and industrial areas

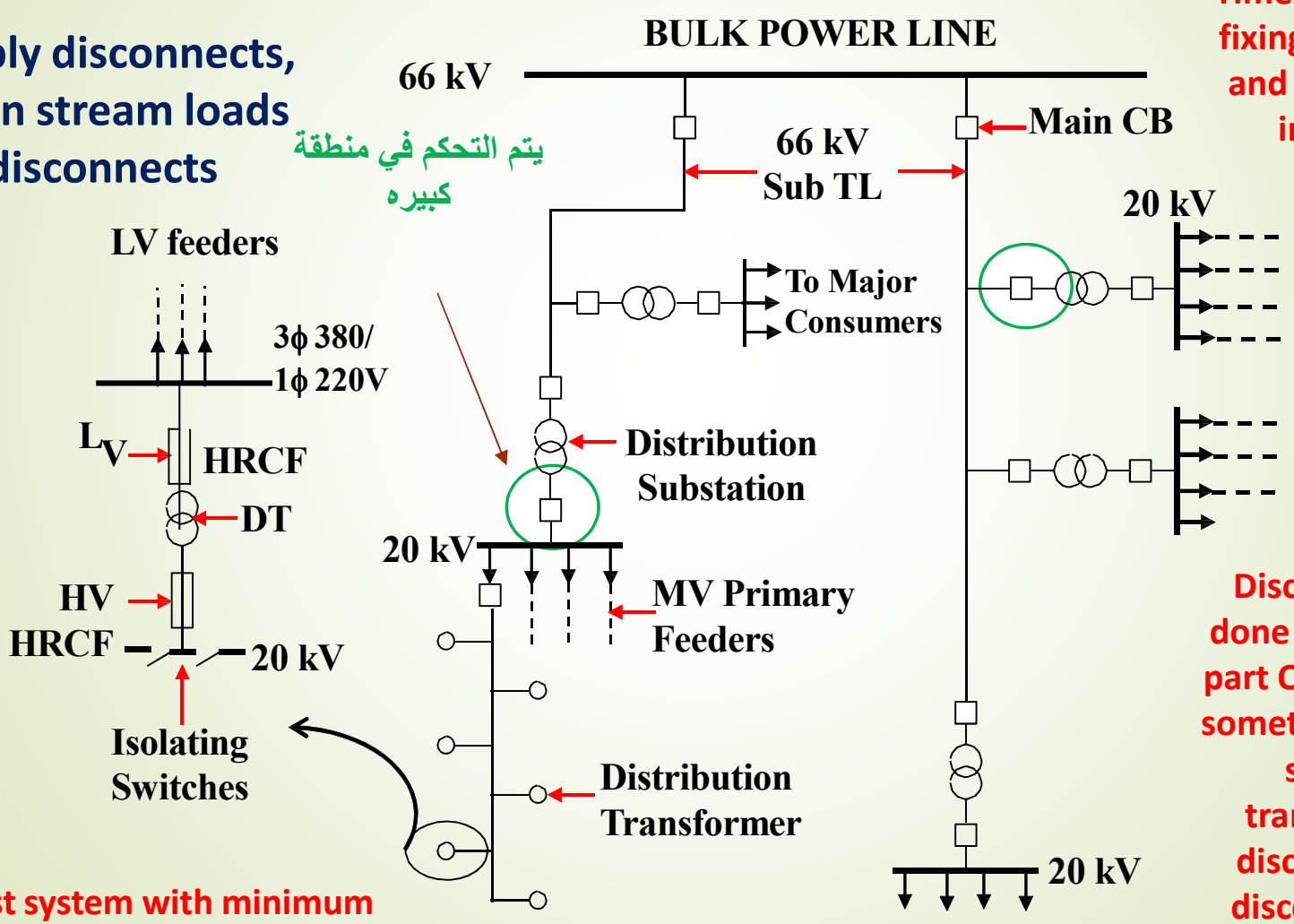
MV Voltage Network: Primary Feeders

1. Radial configuration

التغذية من ناحيه واحده و الحمل من الناحيه التانيه

Supply disconnects, down stream loads disconnects

Time is required for fixing faulted cable and thus power is interrupted



Simplest system with minimum components , cables and cost

Disconnection is done to the faulted part ONLY, however, sometimes the main switch (at transformer) is disconnected to disconnect multi consumers

Radial System: هذا النوع من الشبكات يتواجد في الأرياف والقري Rural areas

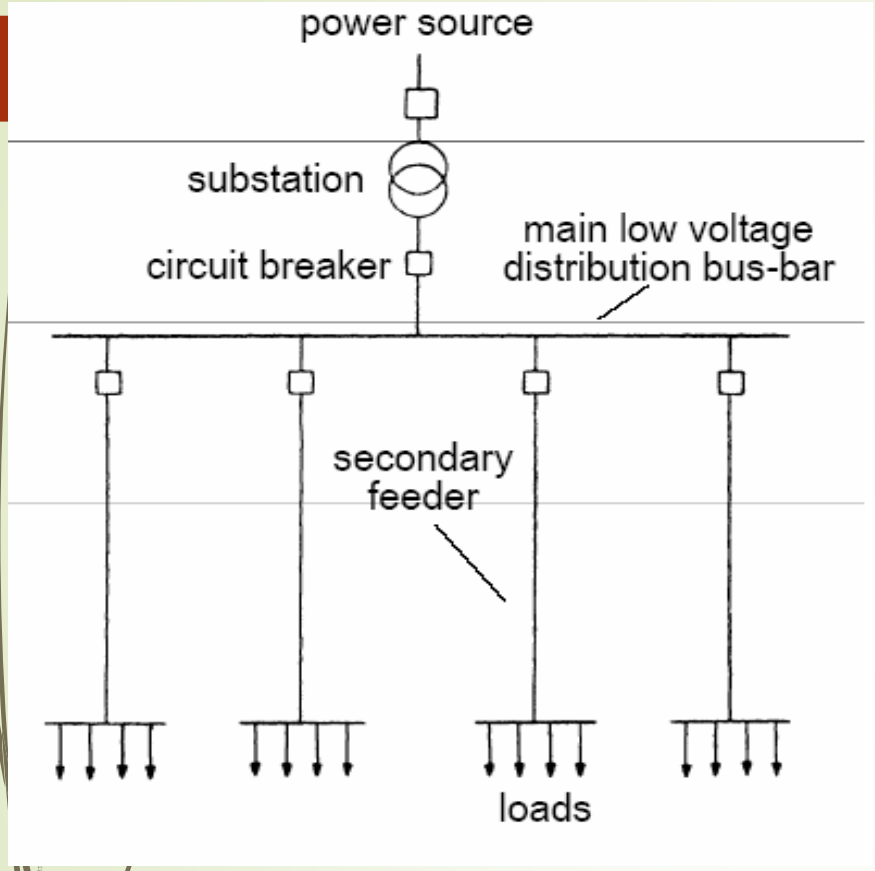
The system offers the following advantages:

- System investment is the lowest of all circuit arrangements.
- Operation and expansion are simple.
- Simpler power flow calculations.

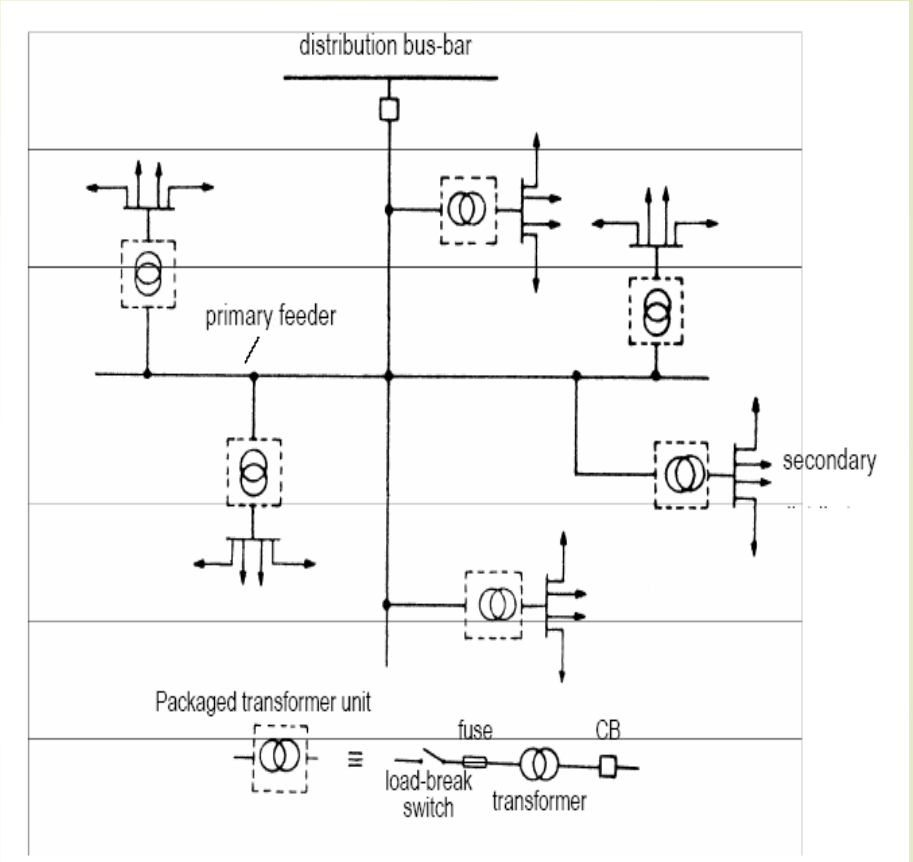
The reliability of simple radial systems has the following characteristics:

- Loss of a cable, primary supply, or transformer will cut off service.
- Equipment must be shut down to perform routine maintenance and servicing.
- When high quality components and appropriate ratings are used reliability is high.
- The system is satisfactory for small industrial installations

Radial Systems

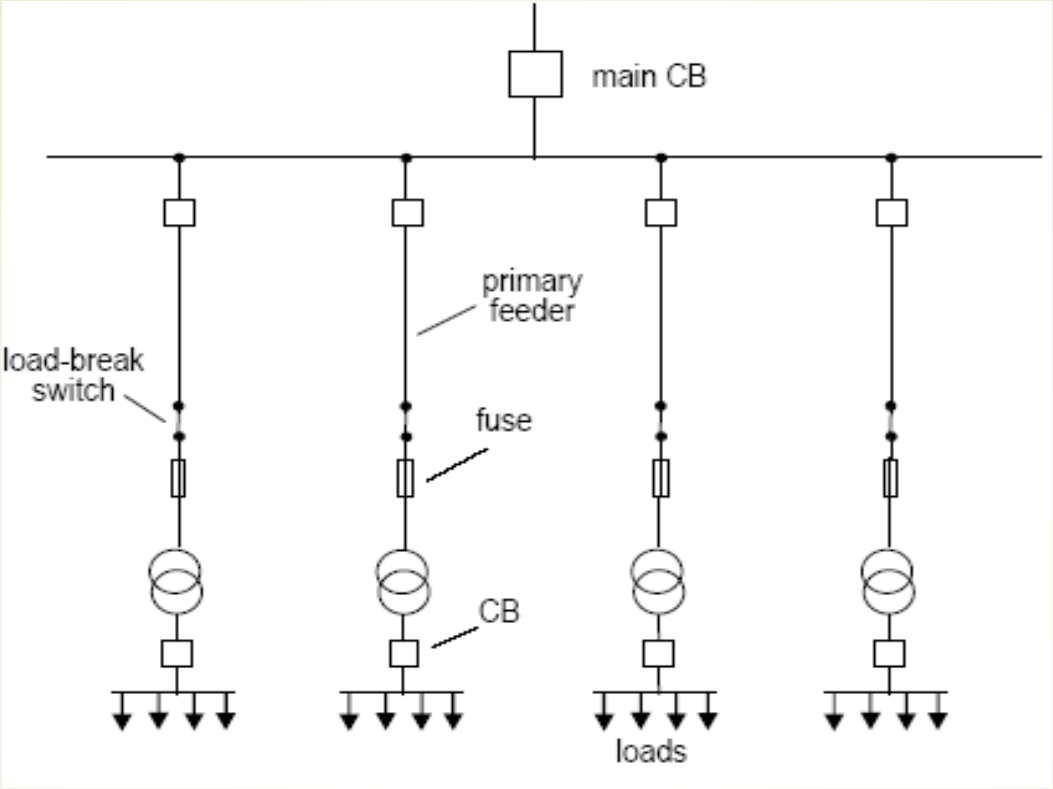


Conventional simple-radial distribution system



Modern simple-radial distribution system

Radial Systems



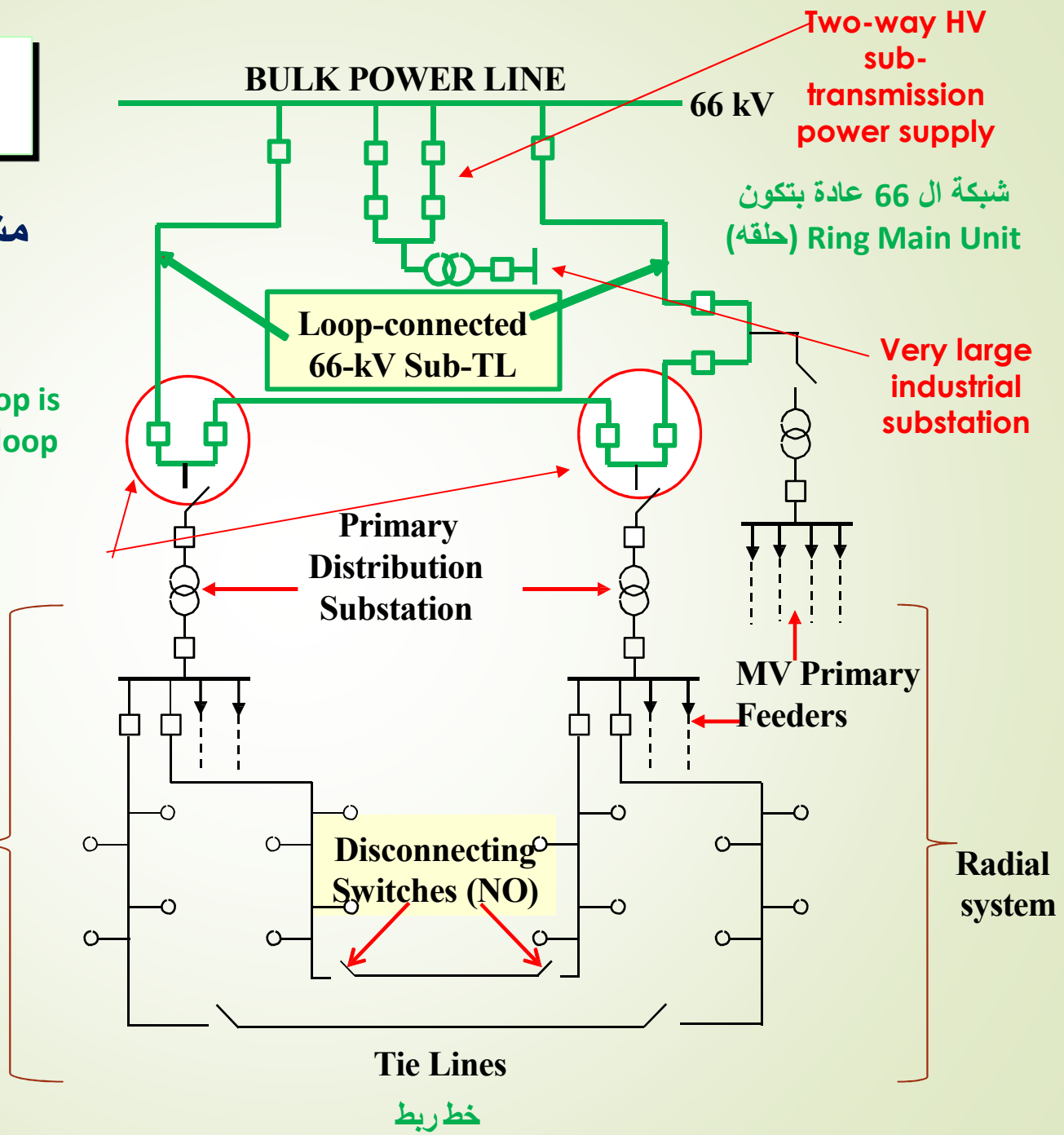
Modified modern simple-radial distribution system

2. Open-Loop Configuration

مشهور جدا في المدن مثل القاهره والإسكندريه

Means that NORMALLY the loop is open and in EMERGENCY the loop closes

Each is fed from TWO WAY power supplies



Open loop Configuration

- شبكة ال 66 لو لم تكن في شكل «حلقة» ده معناه إن عند إنقطاع الكهرباء جزء كبير جدا سيتأثر بهذا الأنقطاع

This is a “normally open system”, this means that normally the downstream acts as a radial system.

In case of any fault in the downstream circuit,

1- First the main section CB trips so that all the downstream cct is isolated from the power source then determines which section is faulted (through SCADA and monitoring station)

2- the disconnecting switches isolates the faulted section and closes the tie line

3- then gets service back again through connecting the main CB again

During fault the system becomes a “loop system” through the connection of the tie line while the faulted part is isolated from the system.

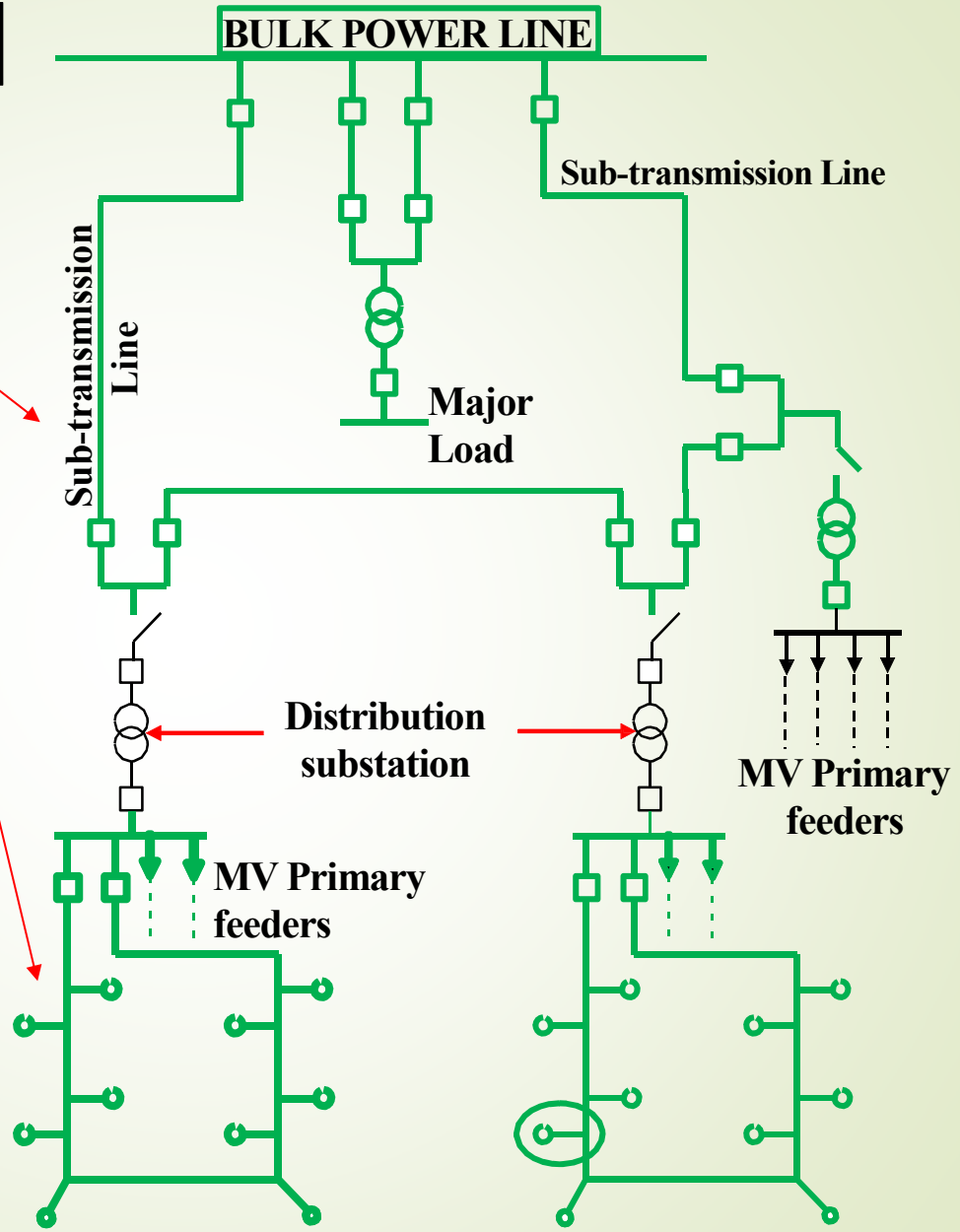
High reliability system

3. Loop Configuration

مشهور جدا في المناطق الحيويه
ووسط المدن

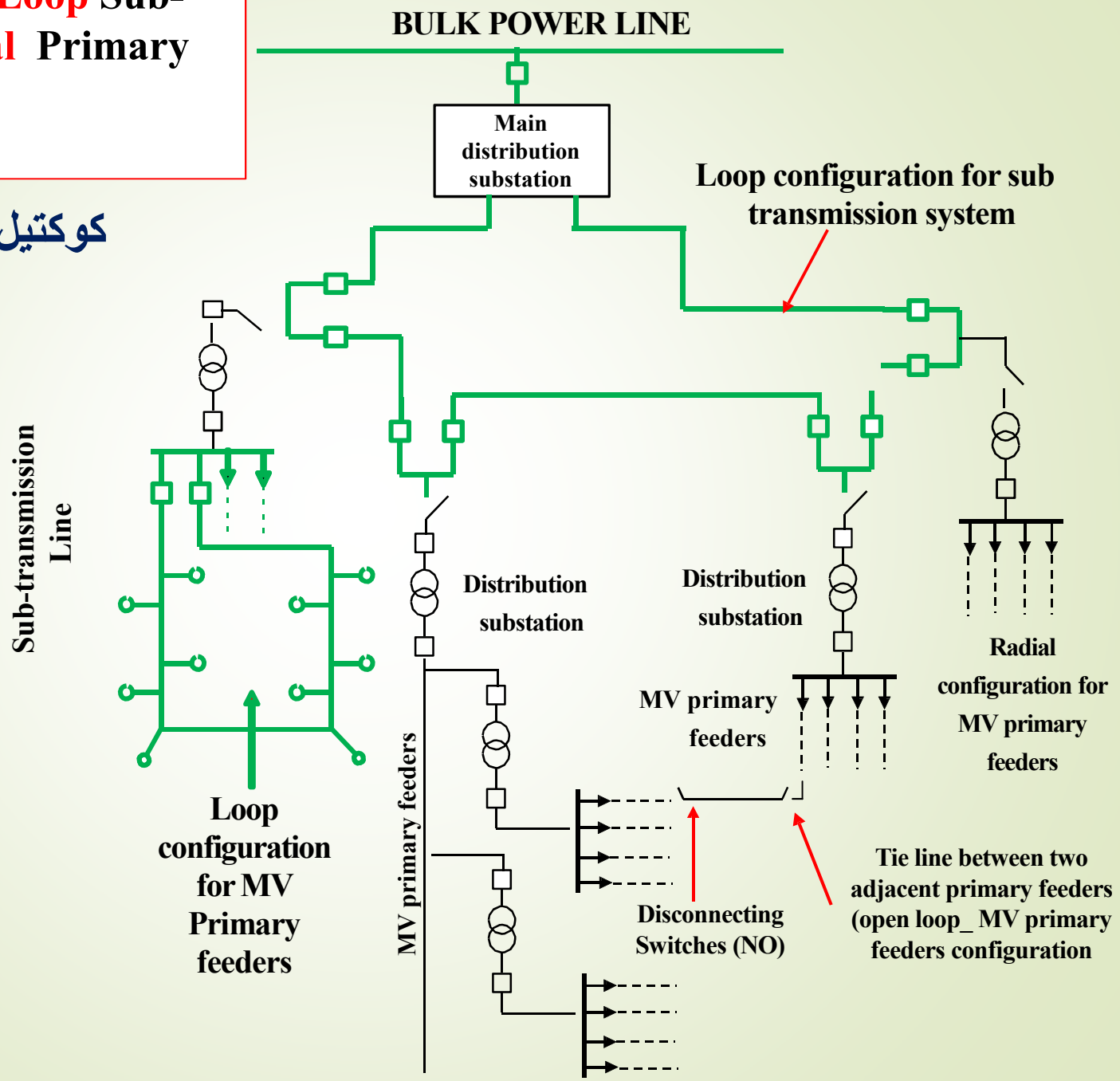
Two loops exist so any load has two supplies

The higher the reliability, the more complex the control and decision making



4. Combination of Loop Sub-transmission & Radial Primary Feeders

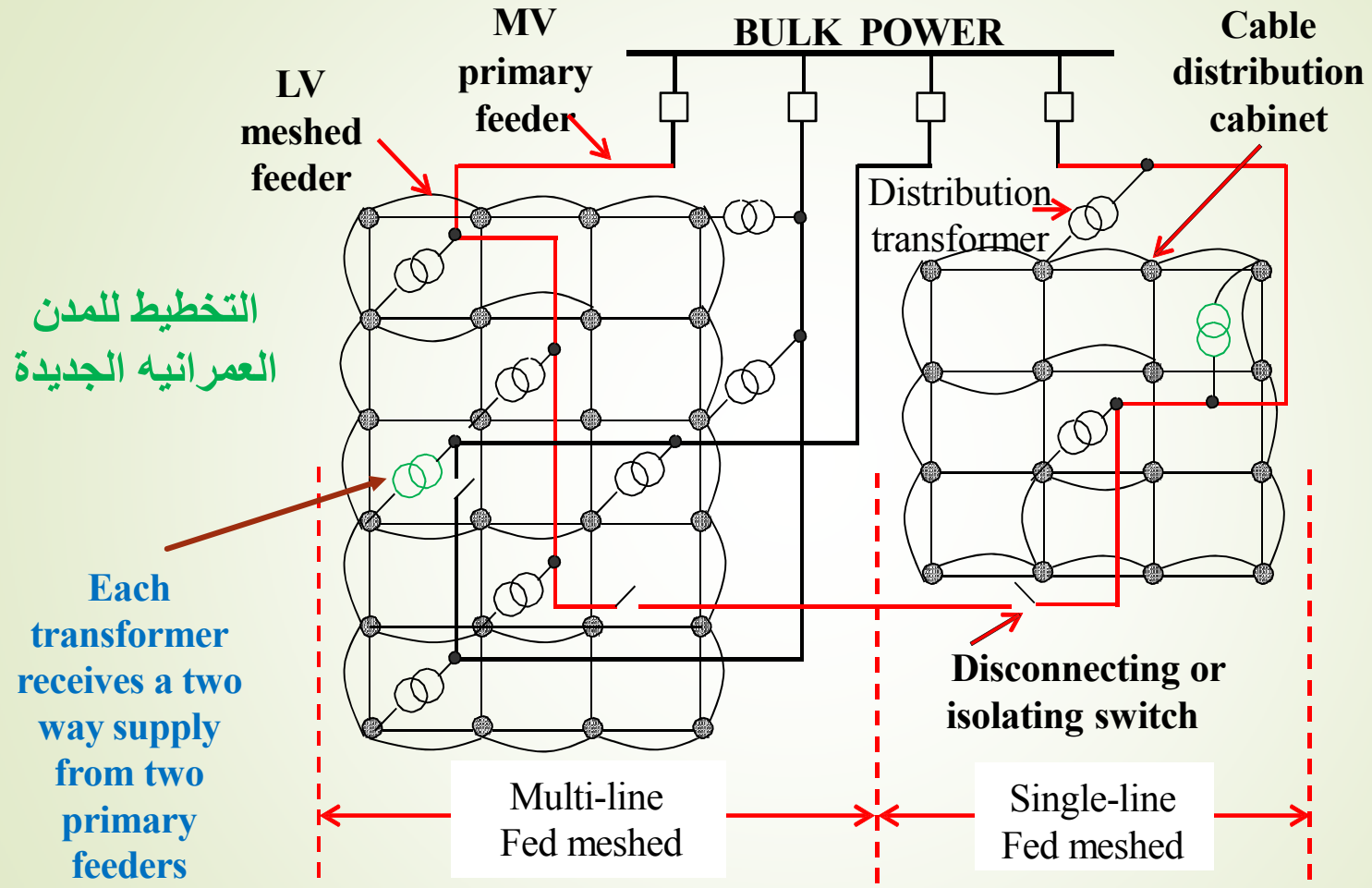
كوكتيل و موجود في القاهرة مثلا



Sub transmission and MV network Layout	Advantages	Disadvantages	Applications
Radial	• Simple layout • Economical to install compared to other layouts	Low reliability	Not used in sub transmission systems
Open loop	• Simple layout • Economical to install compared to other layouts • Provision for switching the load to the good line in the event of supply outage	Failure of one of the two primary feeders leaves a number of consumers out of service until the tie line switches are manually closed	Residential type consumers in urban areas and less density population areas
Loop layout	• Reliable with two way supply • Malfunction section can be repaired without removing much of the sections from service	Expensive and requires more equipment	Residential type consumers in urban areas and less density population areas
Combination (loop and radial)	• Reliable and suitable for critical loads (such as business and industrial loads) • Reasonably econimical	The radial part is arranged so that only residential customers are out of service in case of supply failure	Combination of residential, industrial and commercial customers with a degree of reliability which is load dependent

Low-voltage Distribution Network

Mesh system STANDARDIZED

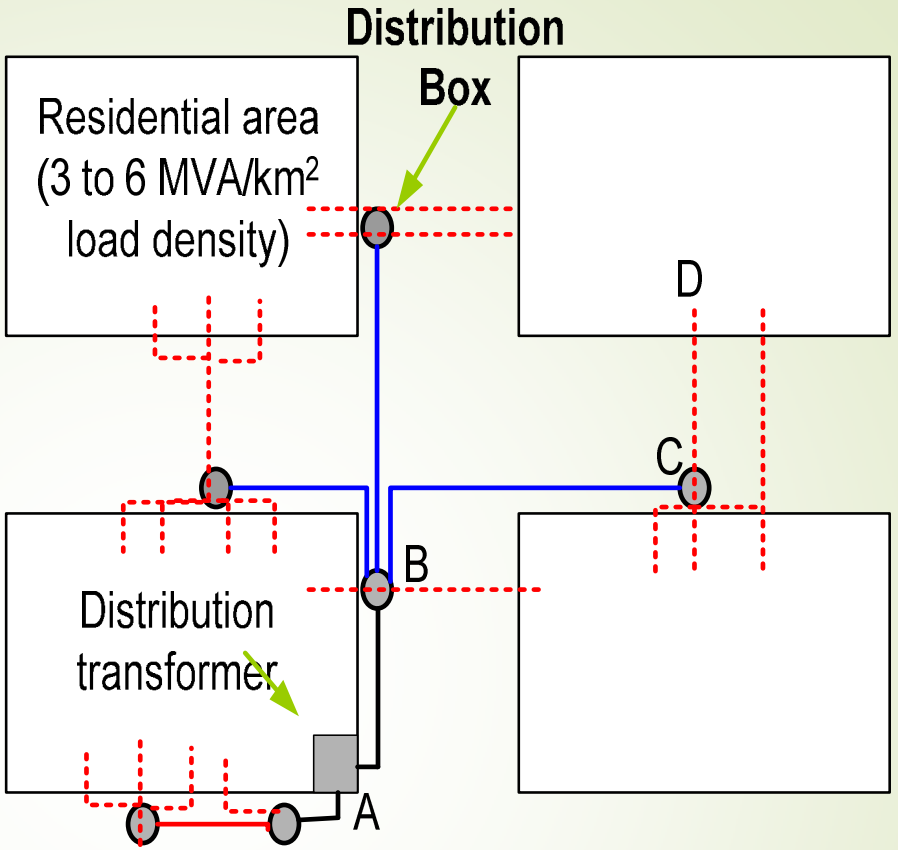


In multi-line fed meshed systems, the substations of several medium-voltage lines can be connected in parallel through the low-voltage system.

In single-fed meshed system, all substations connected via the low-voltage network are supplied from a single medium-voltage primary feeder

Under ground low-voltage radial distribution system 3 to 6 MVA/km² load density

Typical residential area (Street width 7 meters), 5 floors



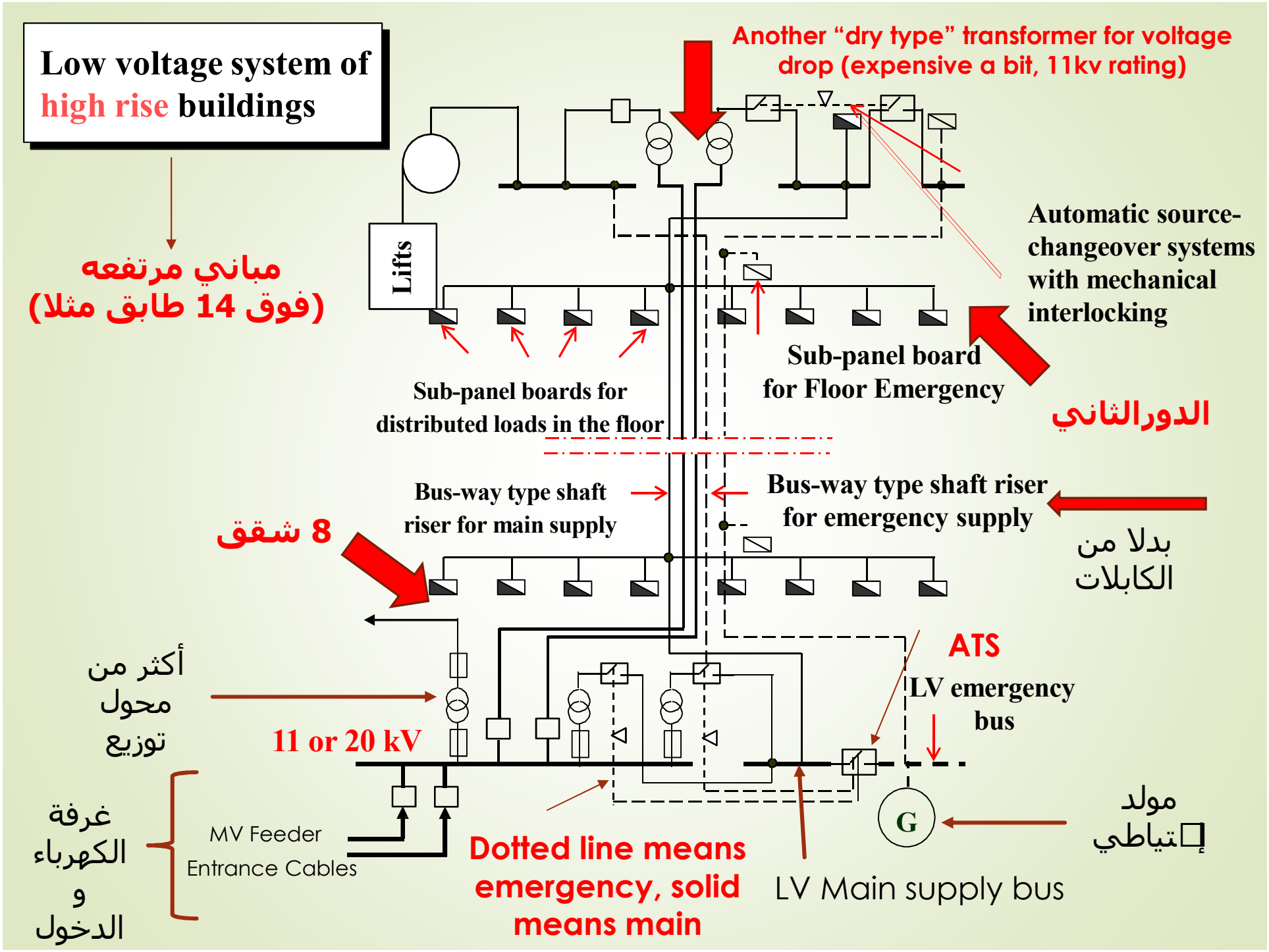
Main cable — 240 mm² 4/C Aluminium conductor 1 kV

Out of distribution box cable — 185 mm² 4/C Aluminium conductor 1 kV

50 mm² 4/C Aluminium conductor 1 kV

To inside SMALL (5 FLOOR)building cable

Or copper equivalent cable


Low voltage system of high rise buildings
مباني مرتفعه (فوق 14 طابق مثلا)
Another "dry type" transformer for voltage drop (expensive a bit, 11kv rating)
Lifts
Automatic source-changeover systems with mechanical interlocking
Sub-panel board for Floor Emergency
الدورالثاني
Sub-panel boards for distributed loads in the floor
Bus-way type shaft riser for main supply
Bus-way type shaft riser for emergency supply
بدلا من الكابلات
8 شقق
أكثر من محول توزيع
11 or 20 kV
ATS
LV emergency bus
غرفة الكهرباء و الدخول
MV Feeder Entrance Cables
Dotted line means emergency, solid means main
LV Main supply bus
G
مولد إحتياطي

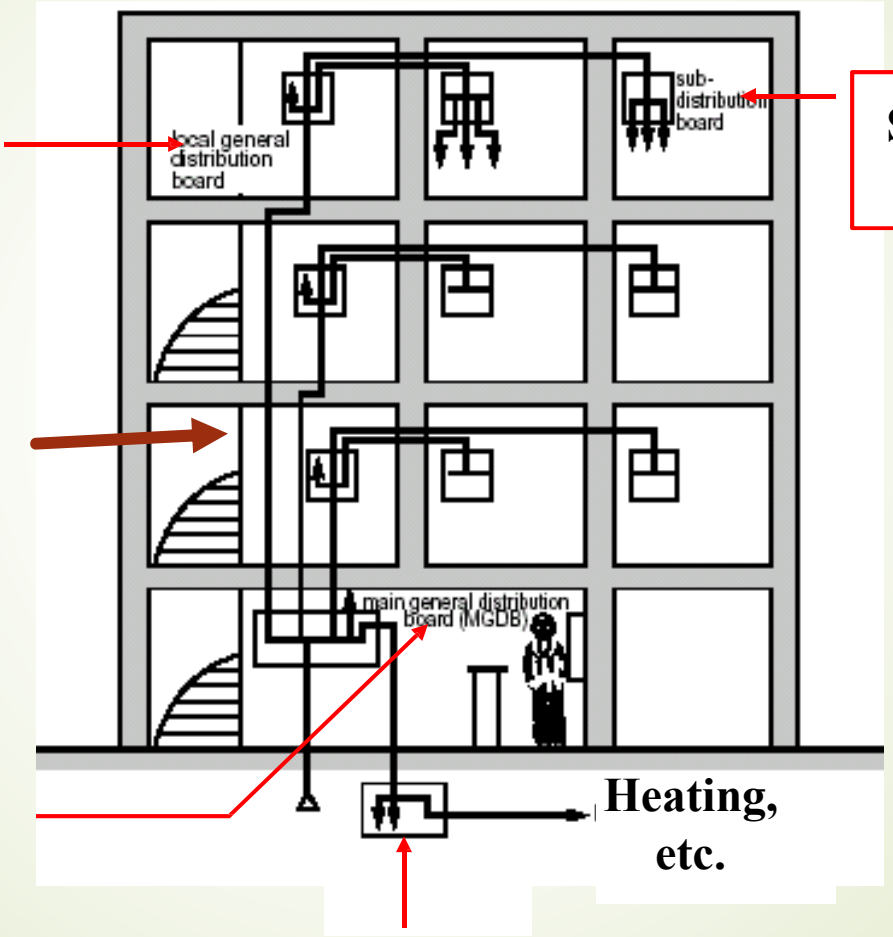
Types of Installation of LV Distribution Systems in Buildings

1. Distribution by insulated conductors and cables:

يستعمل في البنايات ذات عدد طوابق محدود

Local general distribution board

لوحة التوزيع الفرعية



Sub-distribution board

There could be 1 riser or more than one depending on the building size

Main general distribution board

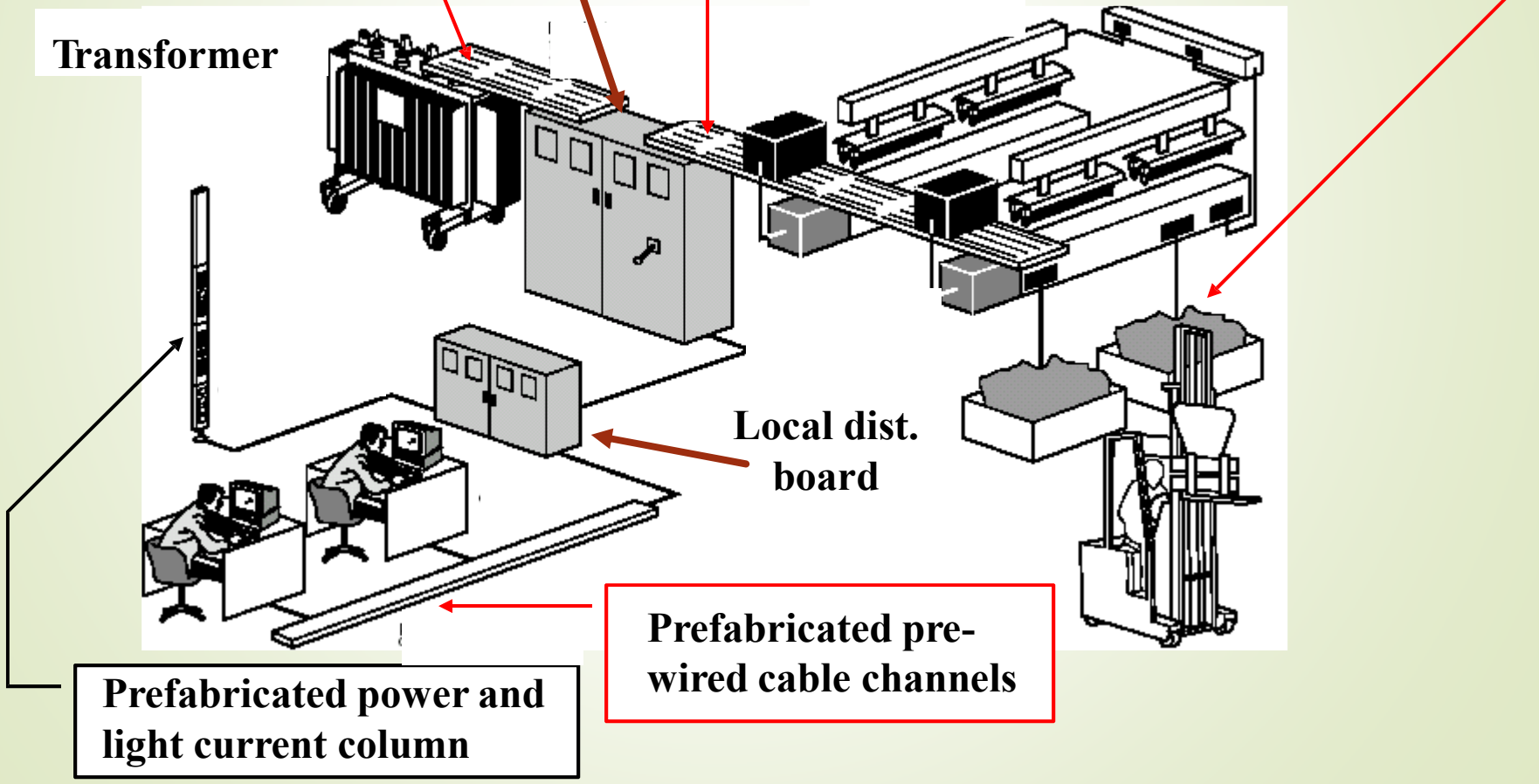
لوحة التوزيع الرئيسية

General utilities distribution board

Types of Installation of LV Distribution Systems in Buildings

2. Distribution by prefabricated bus-trunking & cables channels

Also known as "bus way"



CHALLENGE QUESTION OF THE WEEK! TO BE HANDED IN BY NEXT WEEK IN THE SECTION.

WRITE A "TWO PAGE" SUMMARY ABOUT THE HISTORY AND DIFFERENCES BETWEEN THE IEC AND IEEE

YOUR REPORT MUST:

1- HAND WRITTEN IN CLEAR, NEAT HANDWRITTING

2- INCLUDES REFERENCES

3- MADE BY YOURSELF! IF I FIND SIMILAR ONES, I WILL DISCARD BOTH

4- BE CREATIVE

5- COVER PAGE WITH YOUR NAME AND REGISTRATION NUMBER