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Sept 21, 2015 – Calgary
Sept 22, 2015 – Edmonton
Sept 30,2015 – Fort McMurray
Medium Voltage Distribution

Alberta

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Medium Voltage Distribution

By Sharif Ahmed
of
Siemens Canada
Senior Member IEEE
Rotary Scholar

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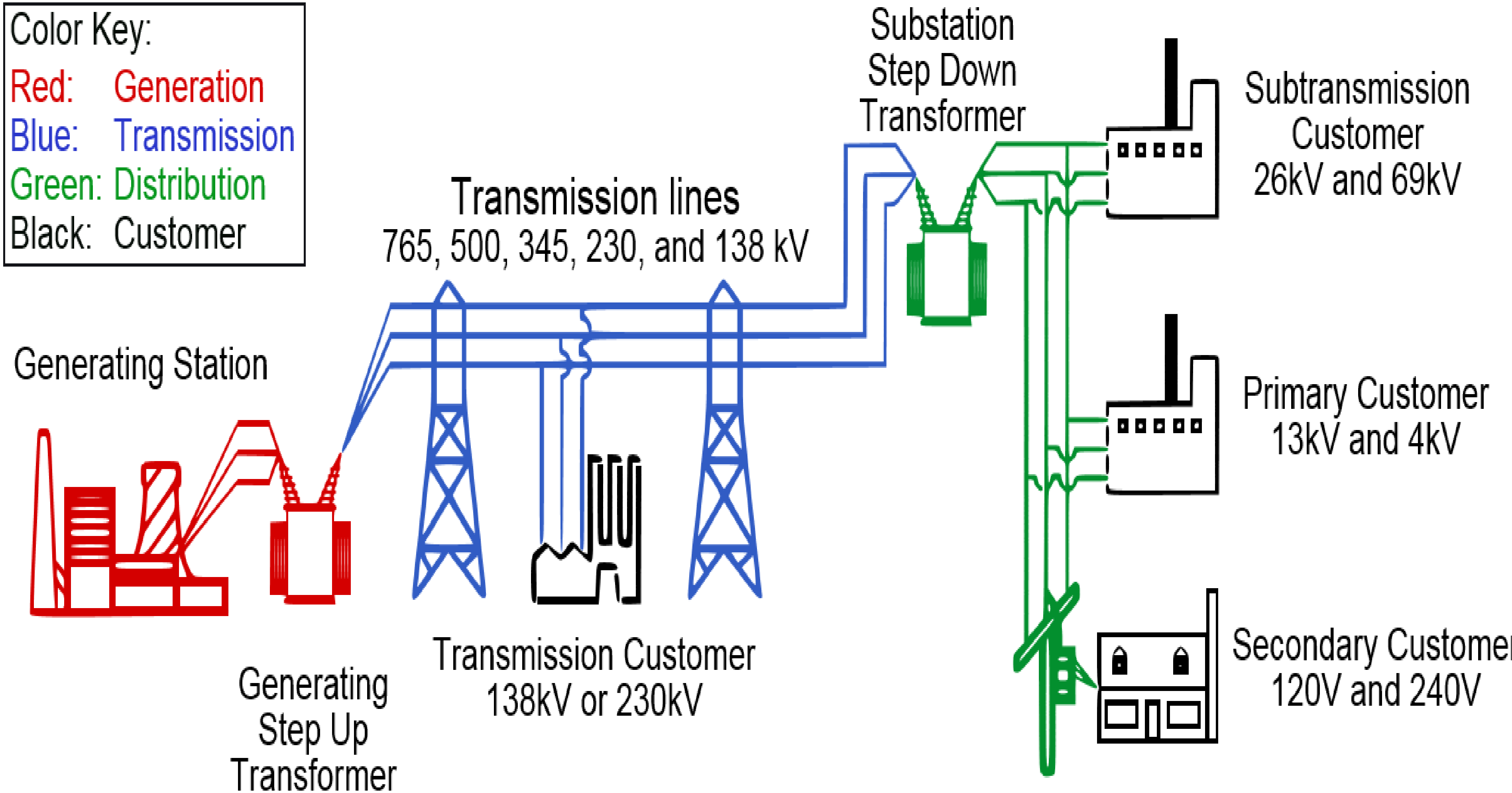

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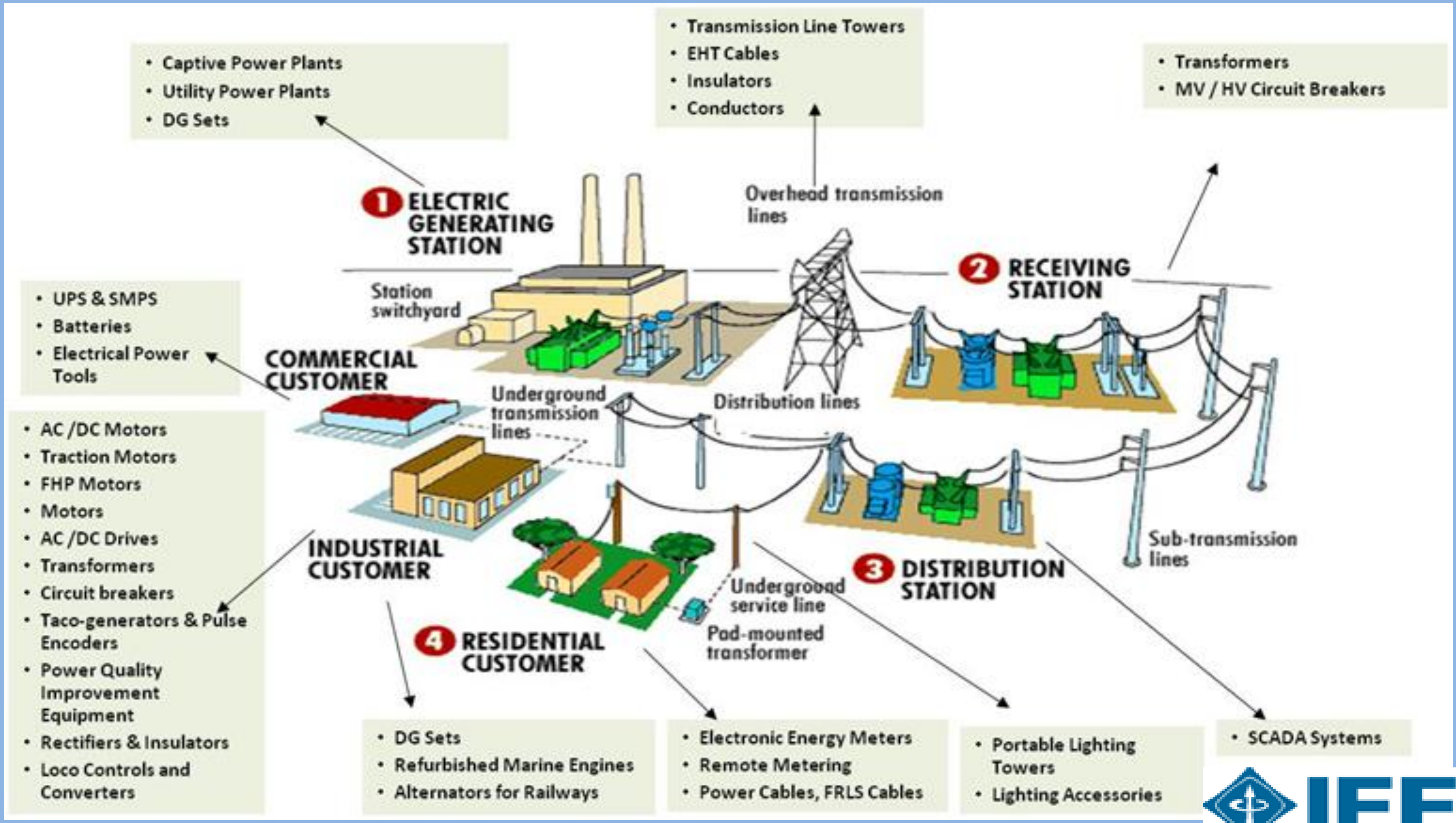
Medium Voltage Distribution

Generation to MV Distribution



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Medium Voltage Distribution

History of Electricity

-*In the beginning Electricity was produced in direct current (DC)*

-*The Generation was done on the same voltage as it was consumed*

- *There was no way of changing the voltage level as the generation was in DC*

-*Then came the Alternating current and it became possible to transmit Electricity on higher voltages.*

Medium Voltage Distribution
Generation

The initial generation was water power or coal

Today the Generation is done through following:-

1. ***Generation by Water Power (Hydro)***
2. ***Generation by Coal***
3. ***Generation by Nuclear Energy***
4. ***Generation by Natural Gas***
5. ***Generation by Wind Generators***
6. ***Generation by Solar Power***
7. ***Generation by Tidal Power***
8. ***Generation by Geo Thermal***
9. ***Generation by Petroleum***
10. ***Generation by Biomass Waste***

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Electricity Generation by Hydro Power

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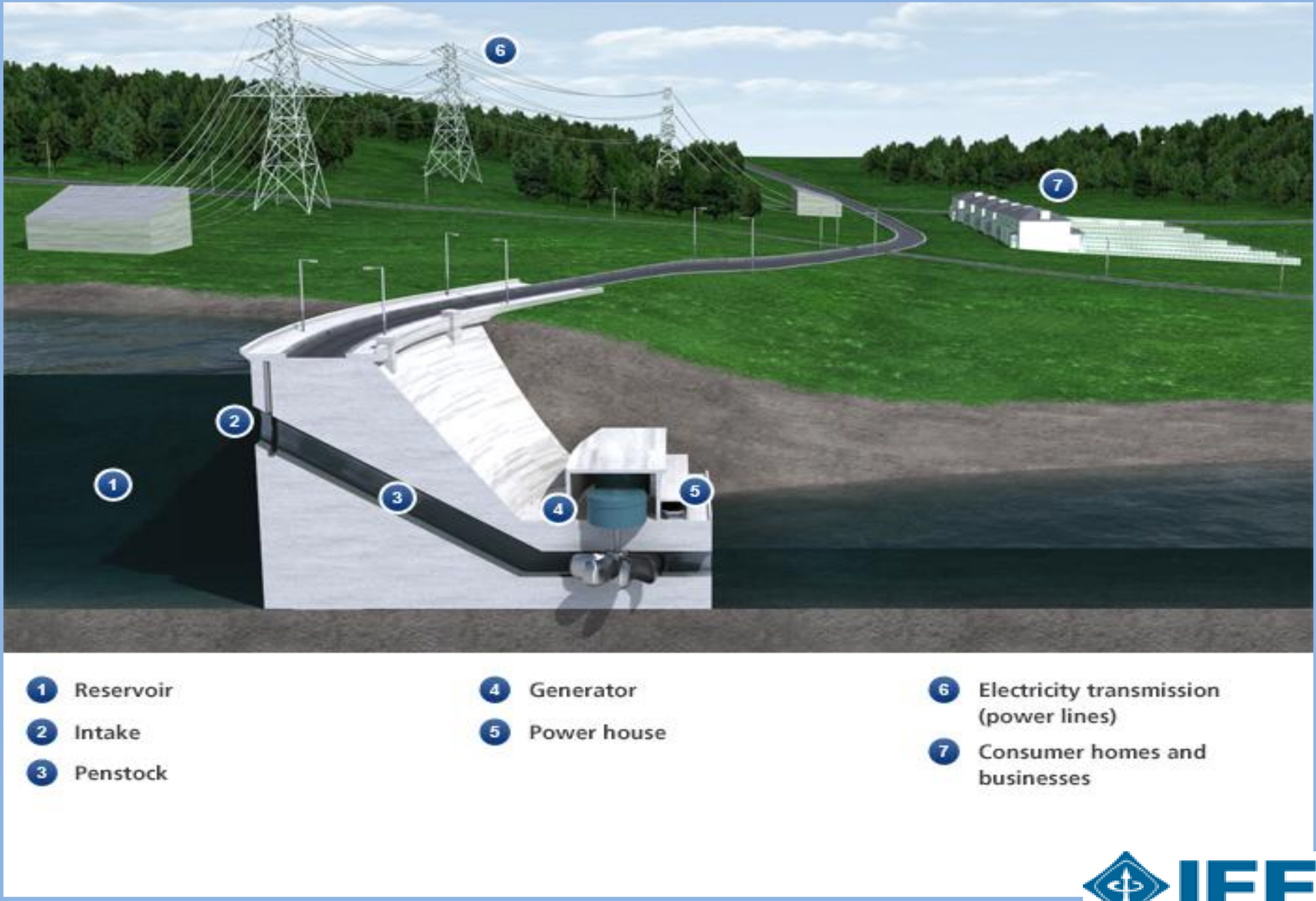
Electricity Generation by Hydro



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Electricity Generation by Coal

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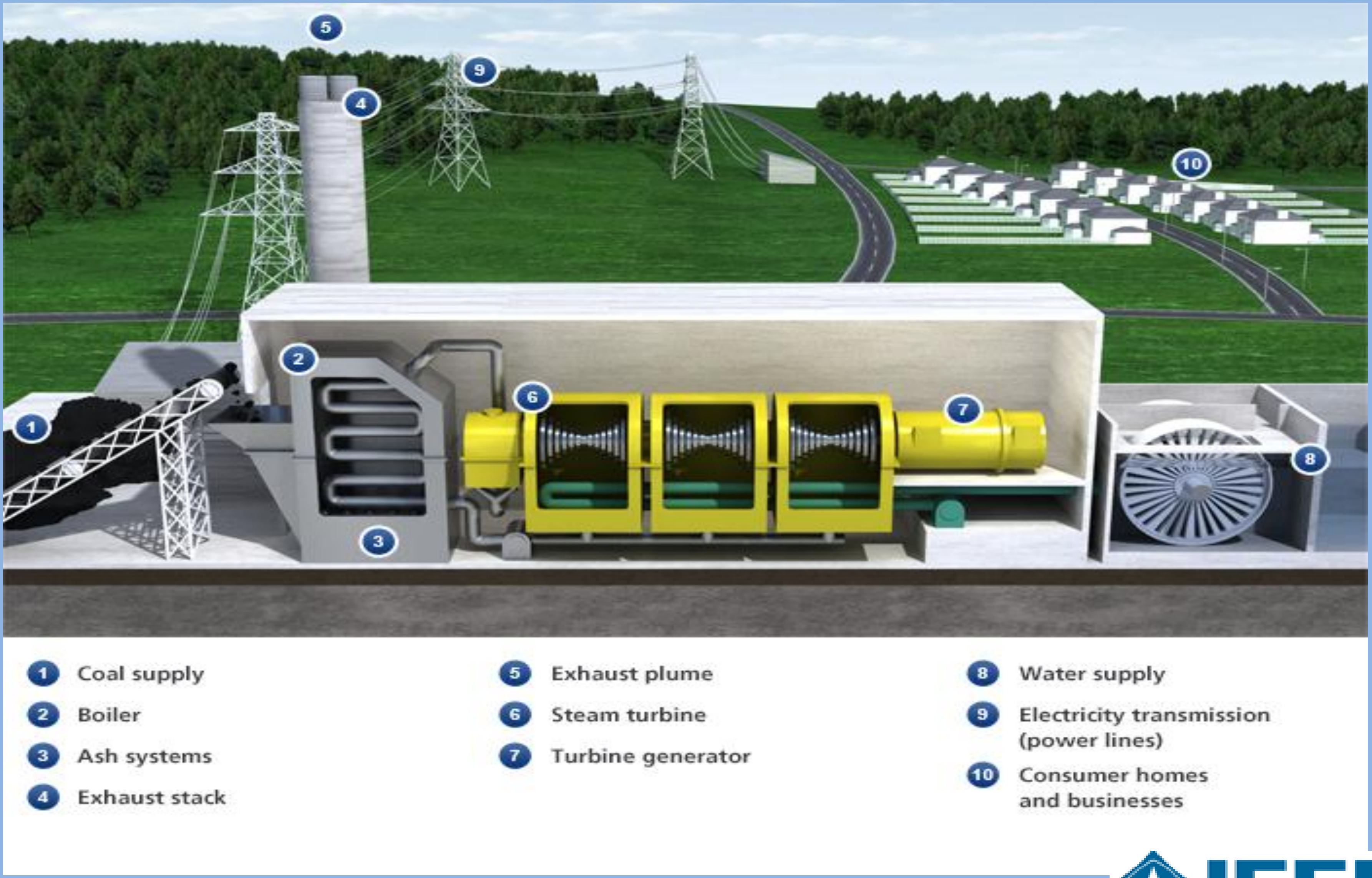
Electricty Generation by Coal



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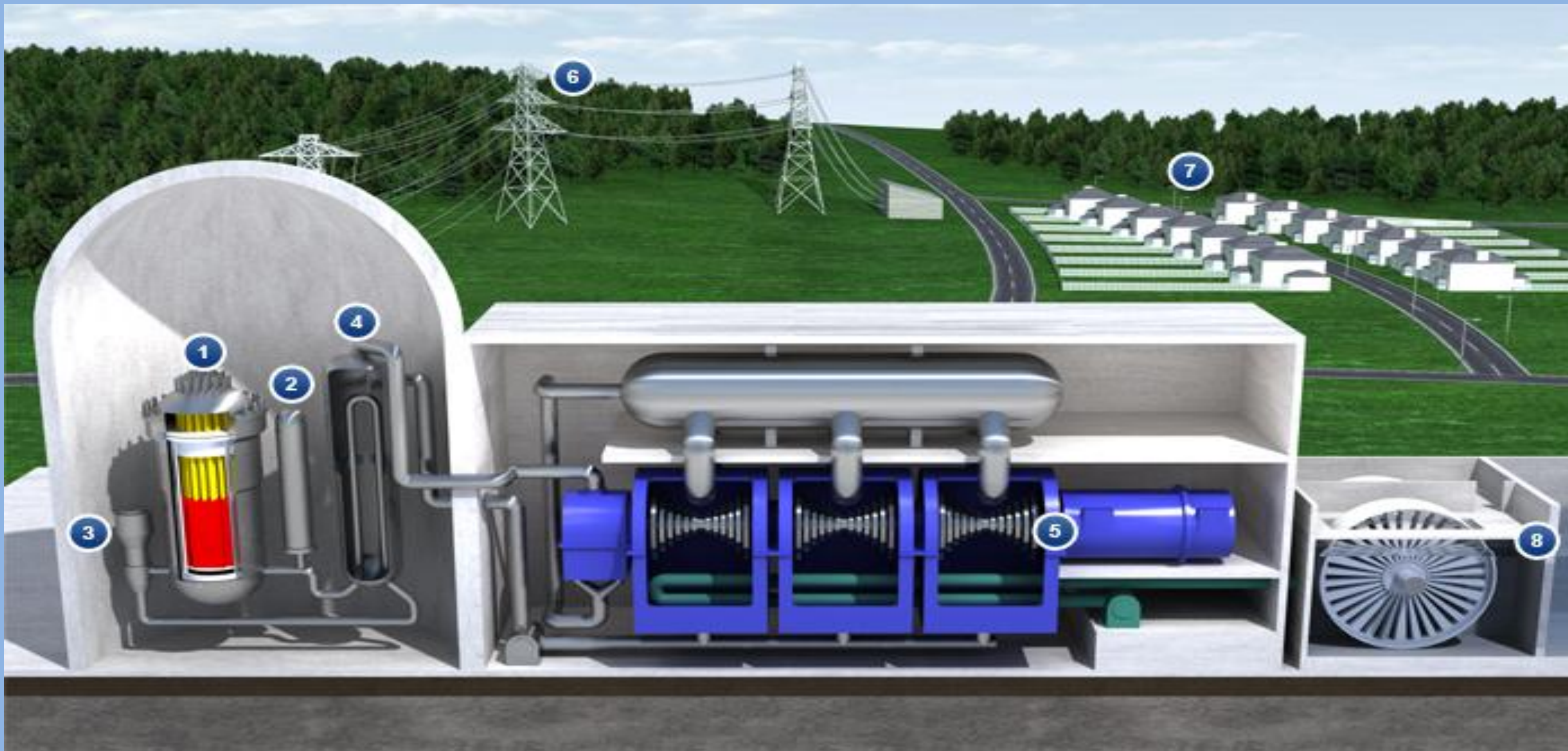
Generation by Nuclear energy



1. Reactor vessel
2. Pressuriser
3. Reactor coolant pump
4. Steam generator
5. Turbine generator and turbines
6. Electricity transmission (power lines)
7. Consumer homes and businesses
8. Cooling via sea water

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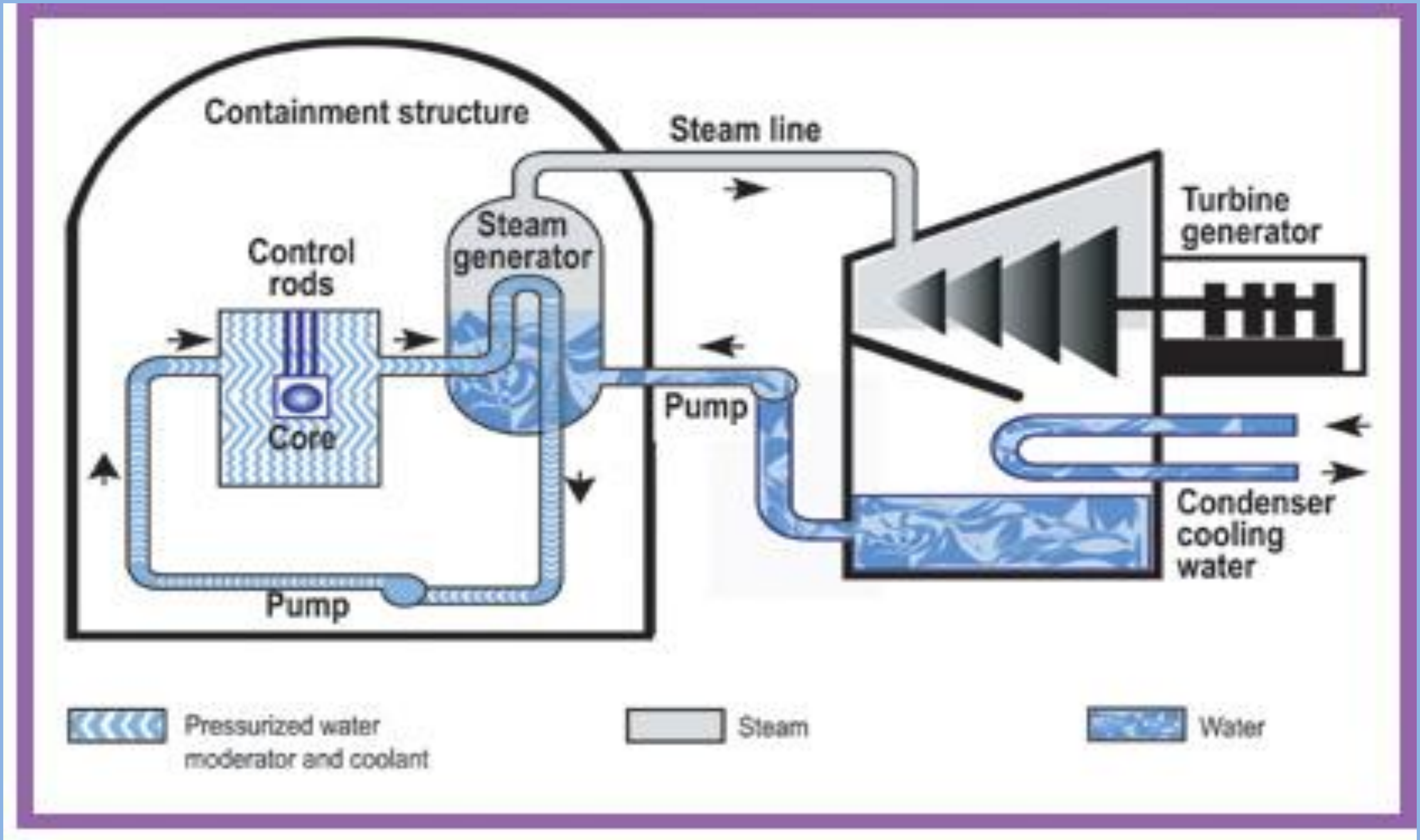
Generation by Nuclear Energy



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Turbo Generators

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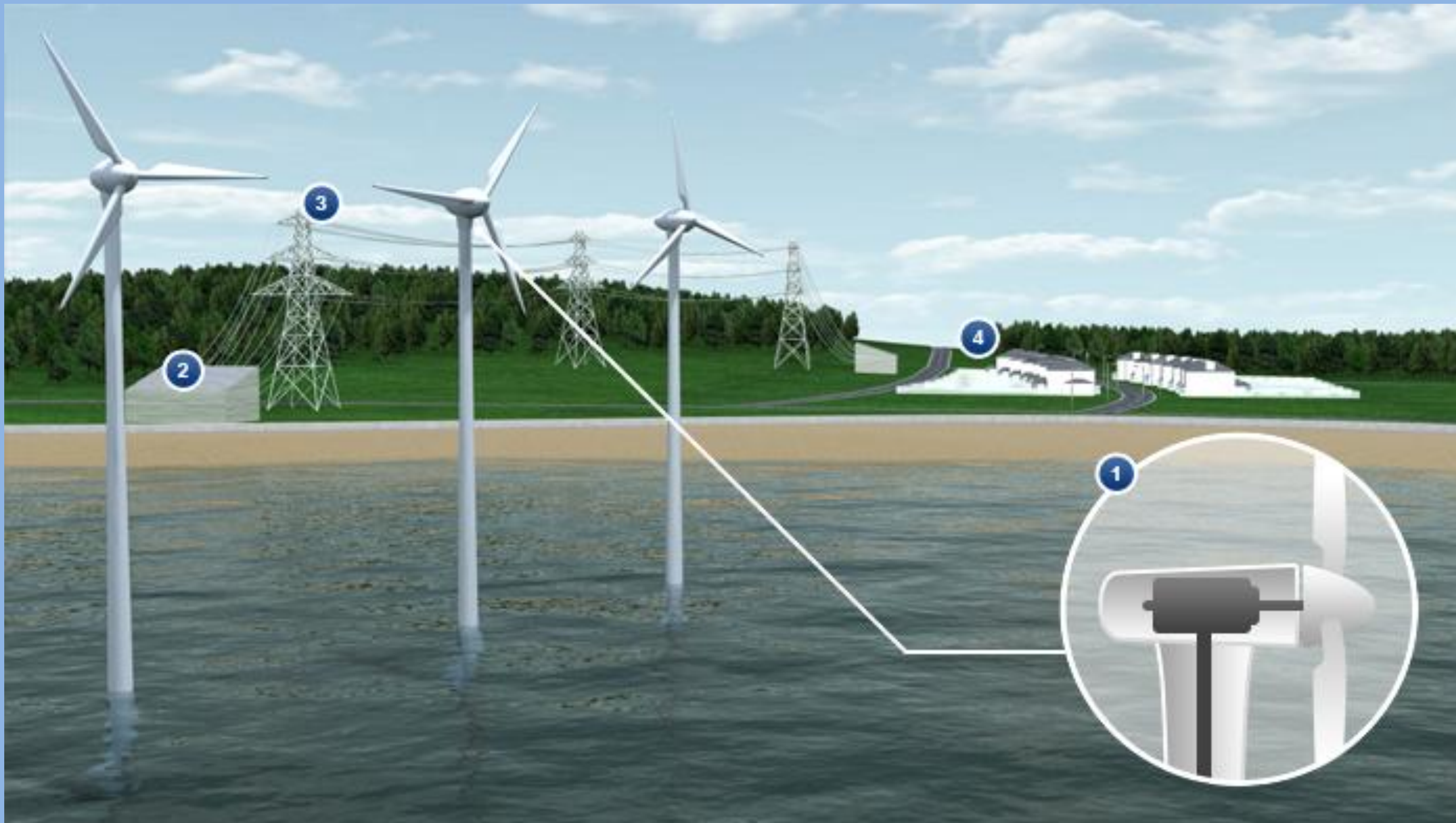
Electricity Generation by Wind Energy



1 Generator (detail)

2 Substation

3 Electricity transmission (power lines)

4 Consumer homes and businesses

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Medium Voltage Distribution Generation by Solar Energy

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Generation through tidal waves

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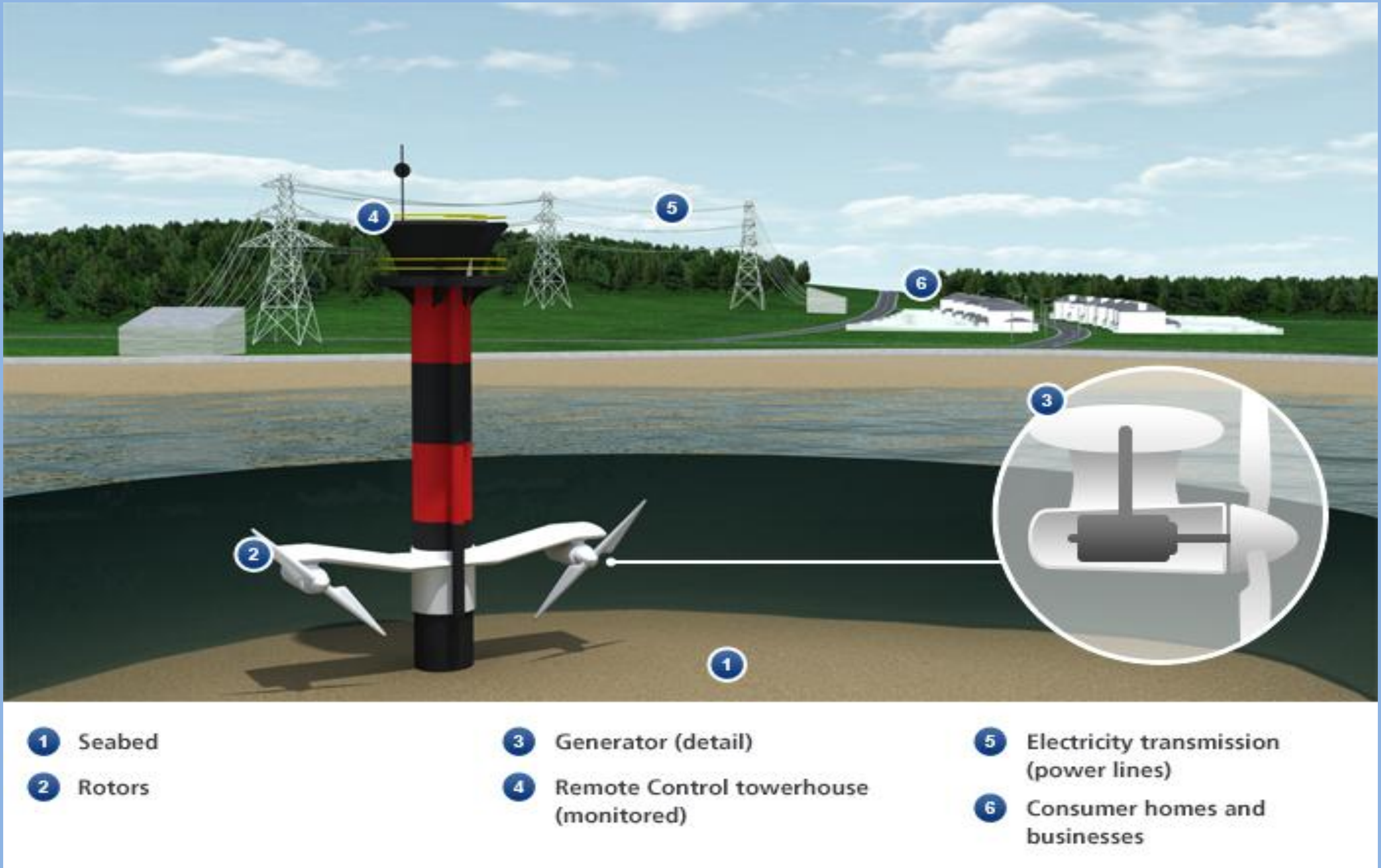
Electrcity Generation by tidal waves



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Generation by Geothermal energy

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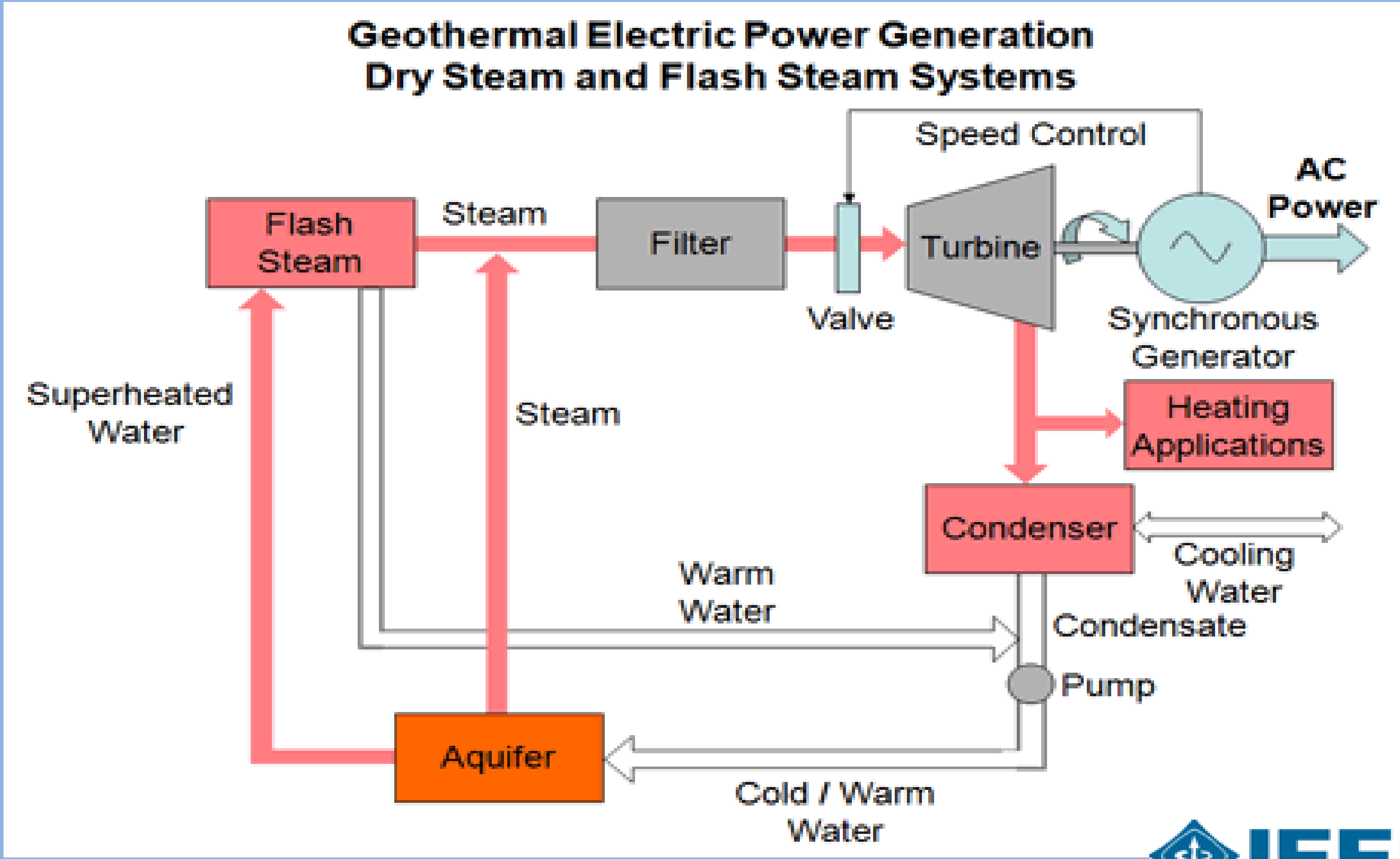


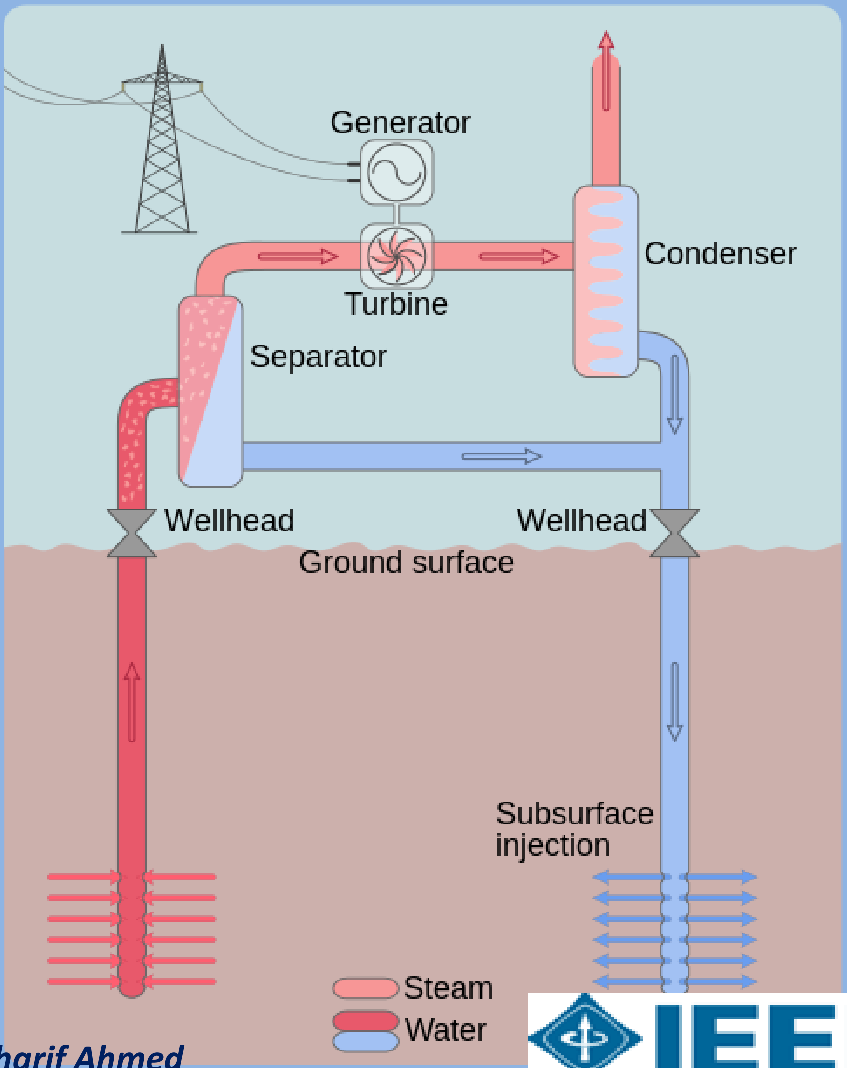
Medium Voltage Distribution Generation by Geothermal Energy

-As per the data collected in the year 2015 the total worldwide Geothermal Generation capacity in the world is 12.8 Giga watts

*-**Out of this total capacity USA generates 3,548 MW***

-- The Geothermal capacity is expected reach 14.5 –17.6 Giga watts by the year 2020.

-- According to a report released by MIT says an investment of 1$billion in R&D in next 15 years would allow generation of 100 GW by the year 2050.



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World's biggest Geothermal Plant in California, USA

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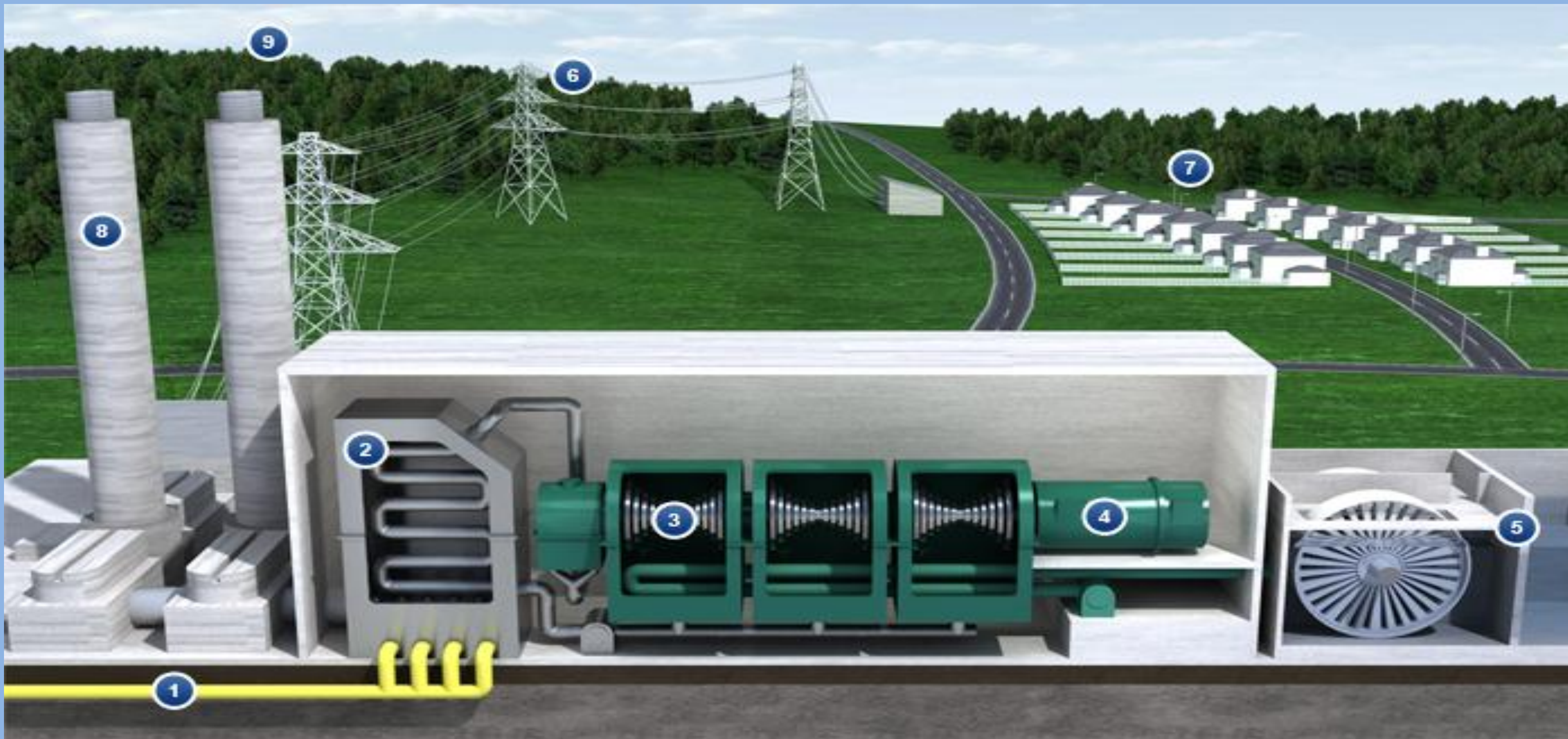
Medium Voltage Distribution
Electricity Generation by Oil



1. Oil supply
2. Boiler
3. Steam turbine
4. Turbine generator
5. Water supply
6. Electricity transmission (power lines)
7. Consumer homes and businesses
8. Exhaust stack
9. Exhaust gas plume

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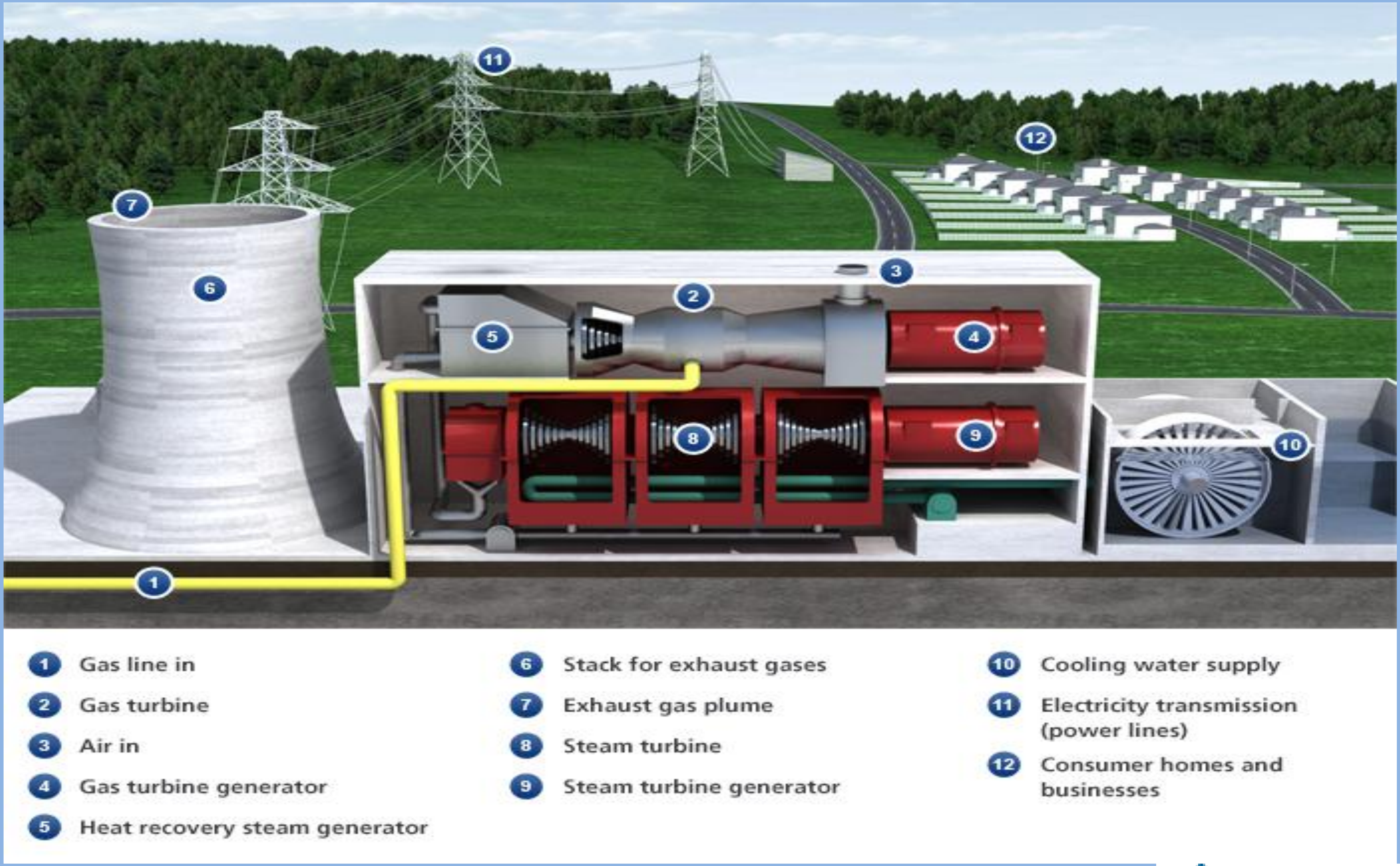
Medium Voltage Distribution
Electricity Generation by Gas



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Electricity produced by Biomass

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Medium Voltage Distribution
One of the Biomass Fuels

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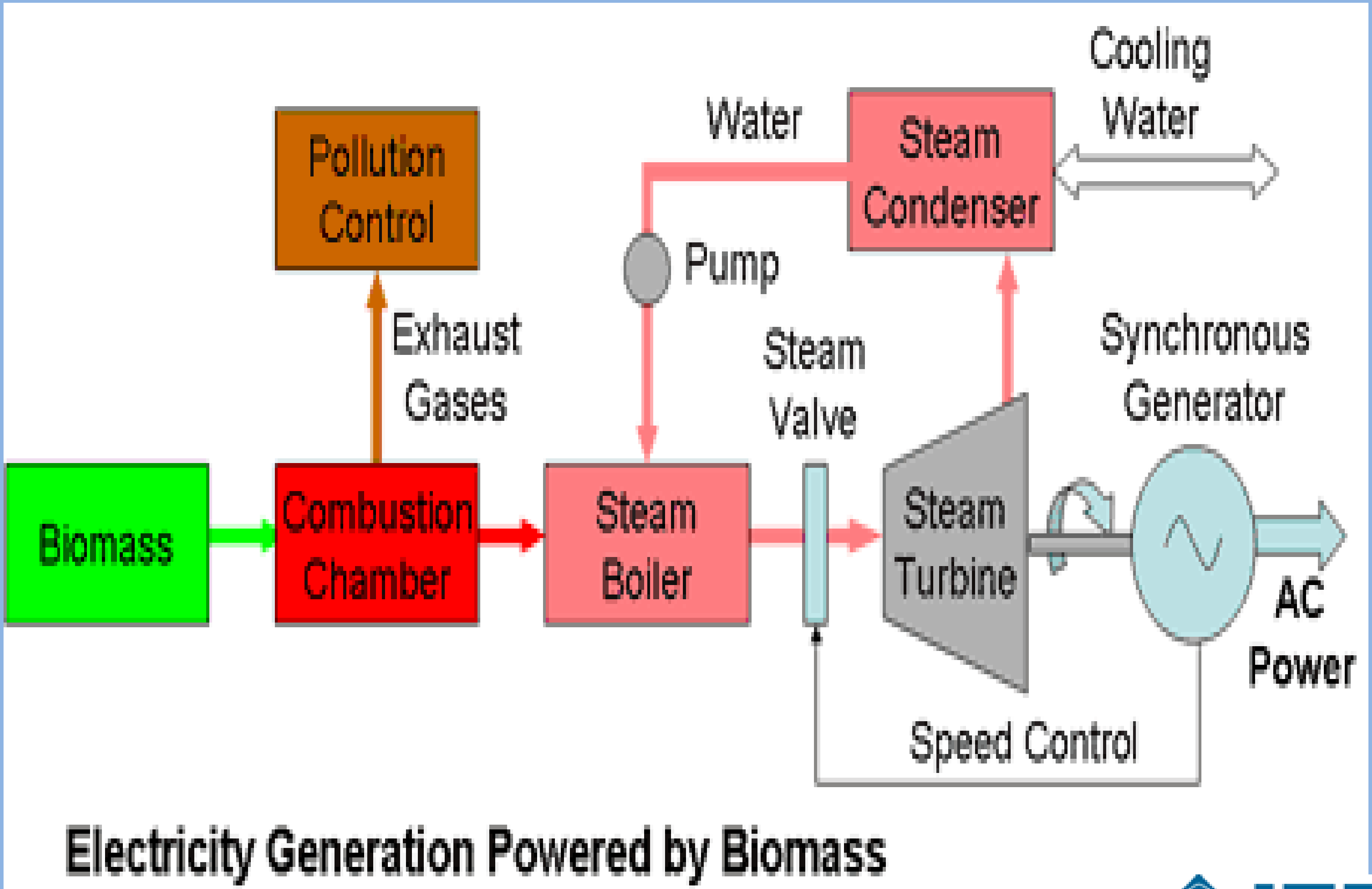
Electricity Generation by Biomass



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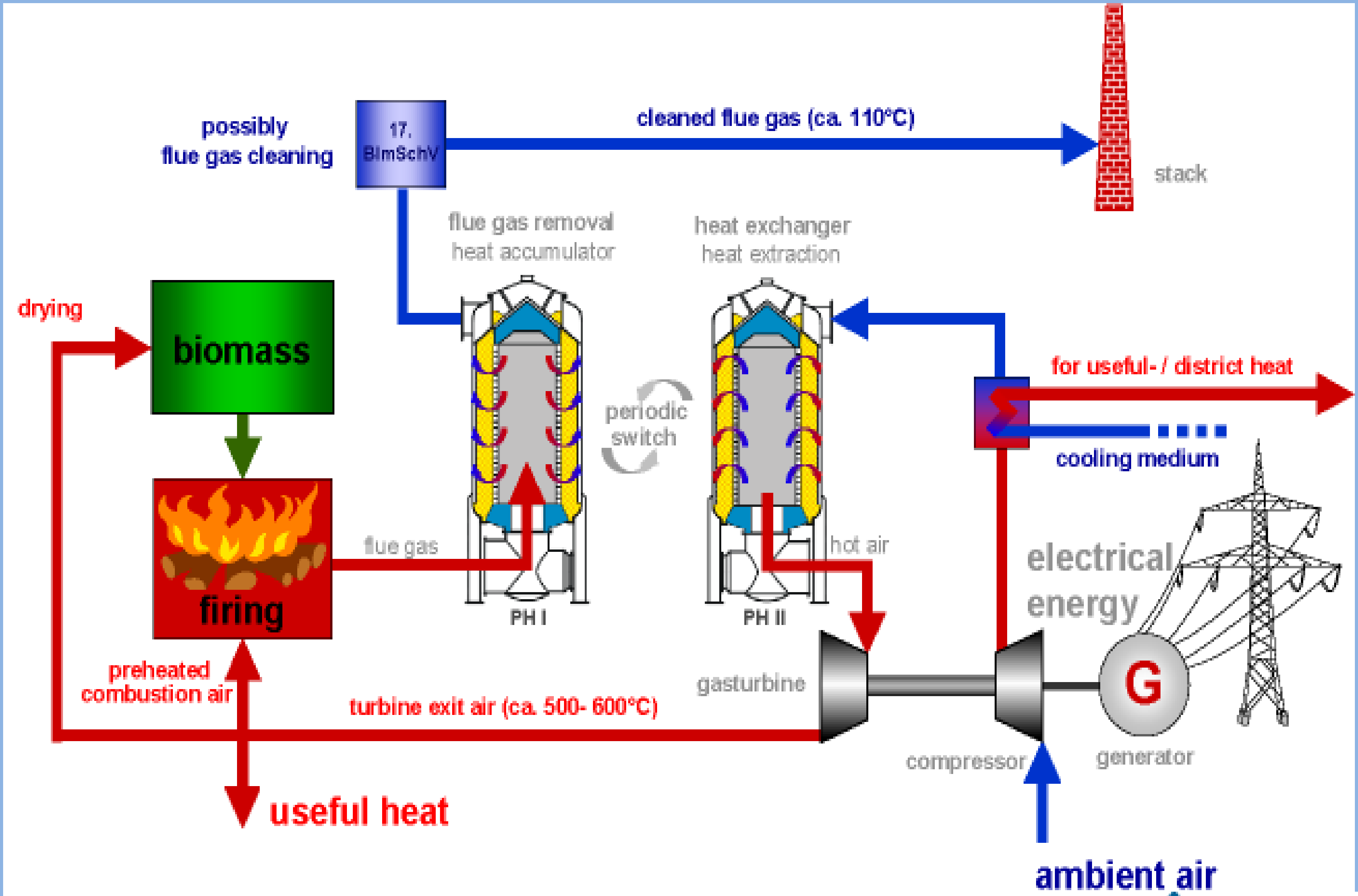
Electricity Generation by Biomass



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Generation Capacity in various provinces in Canada

Alberta 14,598 MW

Saskatchewan 3,902MW

British Columbia 11,000MW

Ontario 35,163MW

Manitoba 5,511MW
Quebec 35,829MW

Nova Scotia 2,293MW

Newfoundland & Labrador 7,289MW

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Medium Voltage Distribution

Generation Capacity in Alberta as of 2014

Generating Capacity	Megawatt (MW)
Coal	6,258
Natural Gas	5,812
Hydro	900
Wind	1,113
Biomass	417
Waste Heat*	86
Fuel Oil	12
Total Generating Capacity	**14,598 MW**

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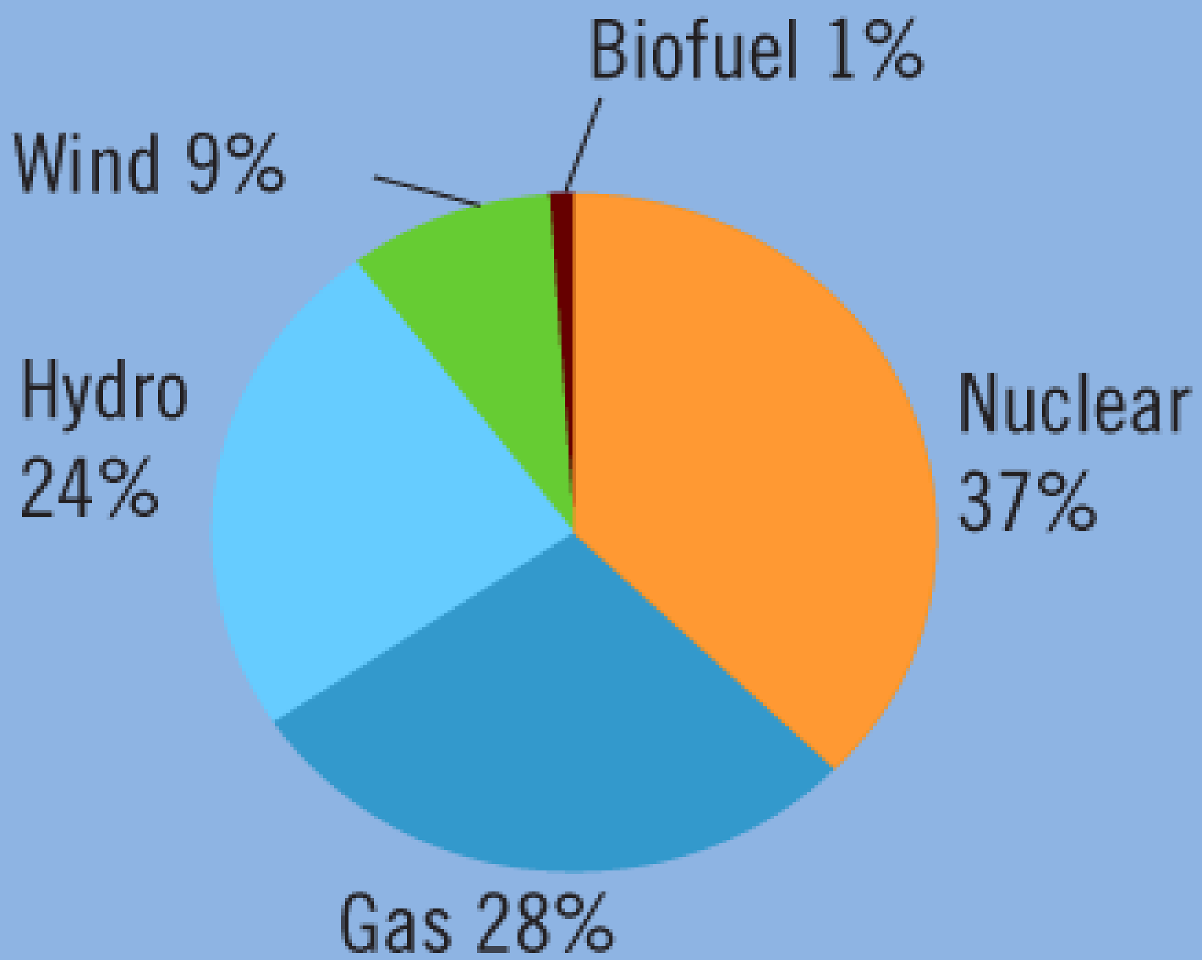
Generation capacity in Ontario(Ref: IESO)



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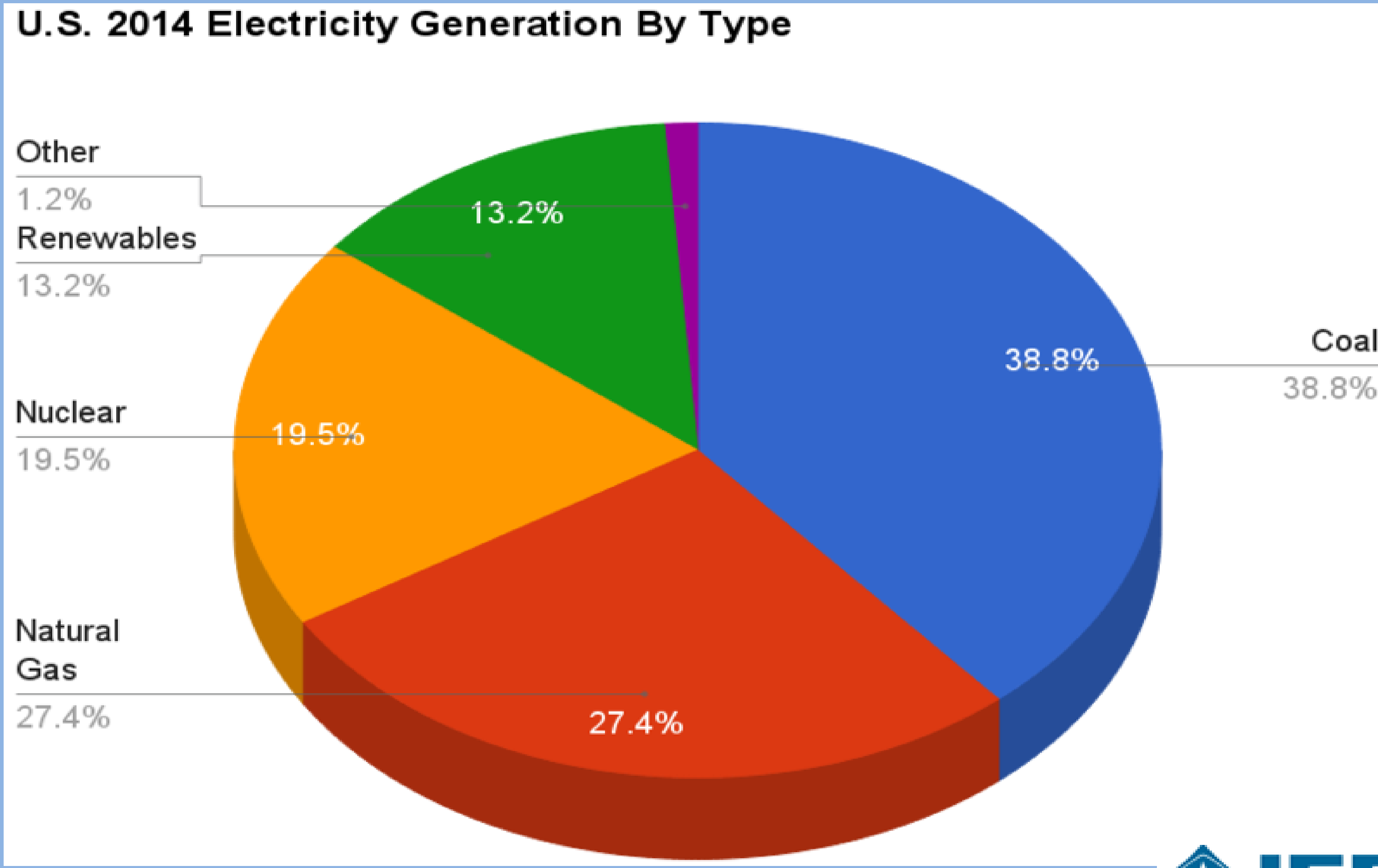
US Electricity Generation



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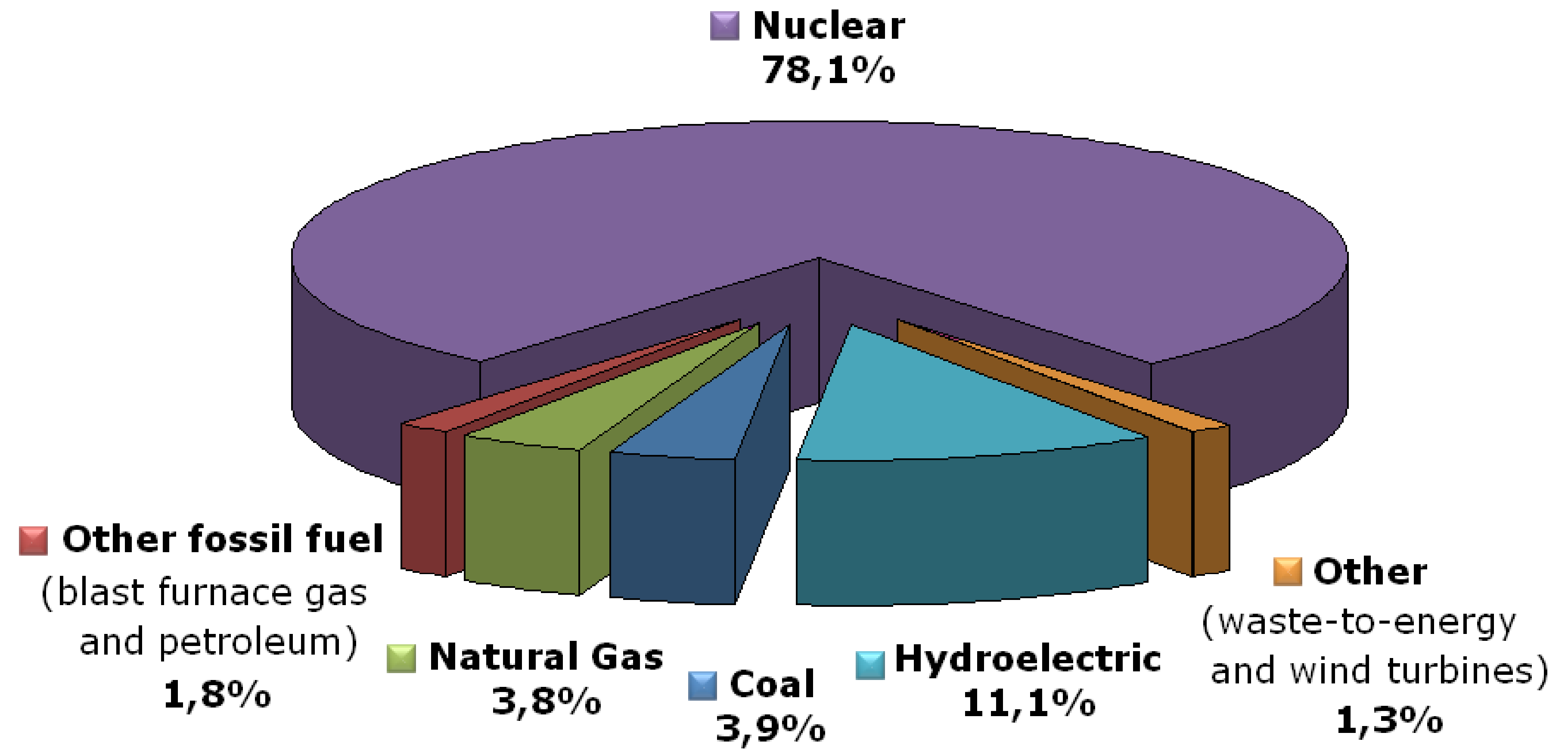
Medium Voltage Distribution Electricity Production in France



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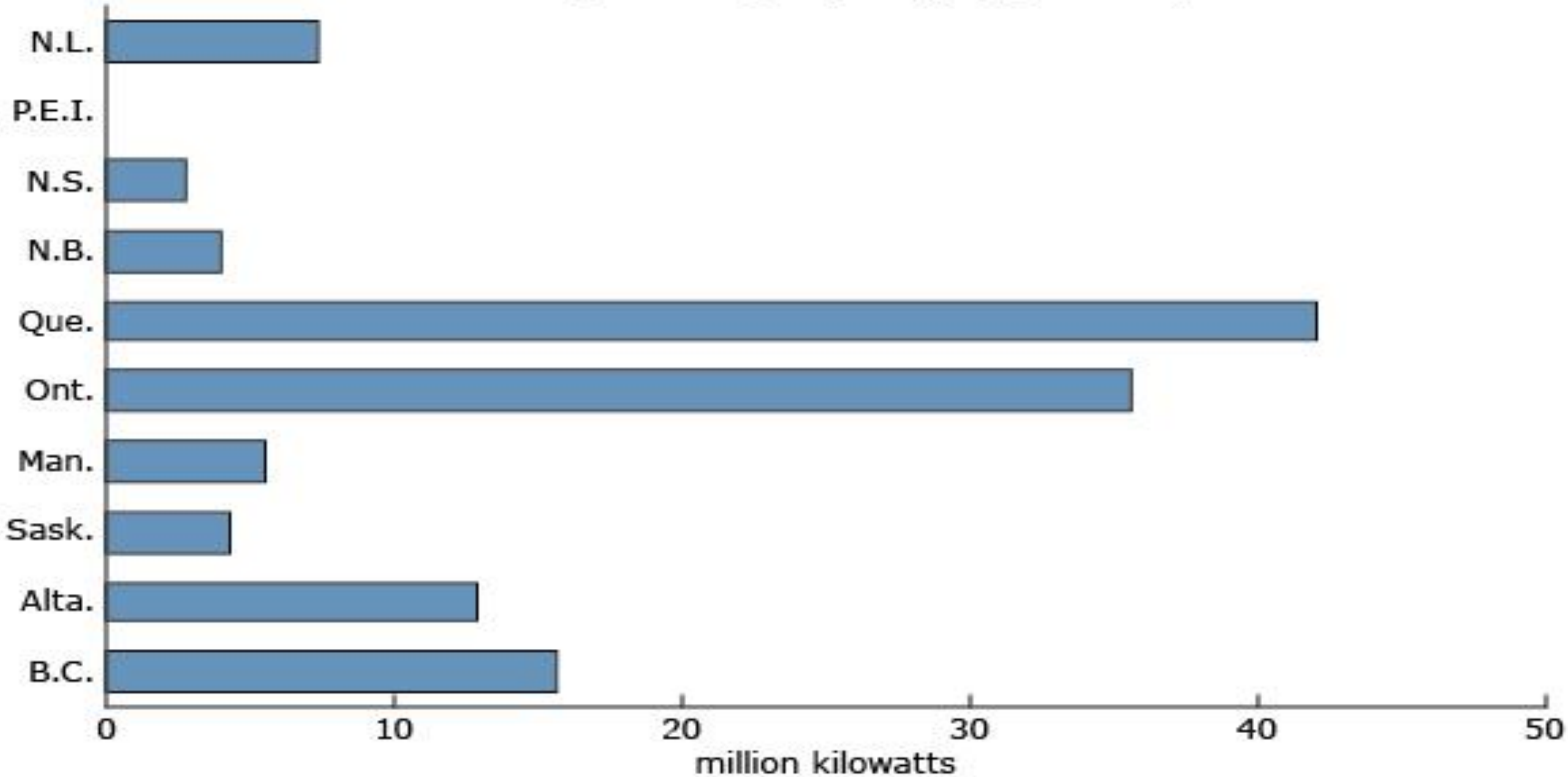
Medium Voltage Distribution

Canada had 130.5 million kilowatts of electrical generating capacity in 2010

Most of Canada's electrical capacity in 2010 was from hydraulic- and thermal-powered turbines, which produced 75.1 million kilowatts (57.5%) and 51.4 million kilowatts (39.3%), respectively. Quebec accounted for 51.2% of Canada's hydraulic power in 2010, with a capacity of 38.4 million kilowatts. Ontario (25.5 million kilowatts) and Alberta (11.1 million kilowatts) provided most of Canada's thermal capacity; 47.0% of Ontario's thermal capacity was from nuclear steam turbines

Medium Voltage Distribution Generation Capacity in Canada

Chart 11.2 Installed electrical generating capacity, by province, 2010



Source: Statistics Canada, CANSIM table 127-0009.

Medium Voltage Distribution Power Transformers

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Medium Voltage Distribution Power Transformers

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The Transformers used for stepping up the Voltage are selected on following:

1. The MVA Rating is selected on the basis of the Power to be transmitted.

1. The Transformer Losses are to be defined or a capitalization of Losses formula is to be given while procuring a Transformer in order to be sure to buy the right Transformers with optimum Losses as this is money you lose over the life time of the Transformer if you buy a transformer with higher losses. A transformer with higher losses is cheaper in price but you lose money over the period of time.

1. The impedance of a Transformer is calculated after the short circuit calculation of a net work. Lower the impedance higher the sort circuit capacity in a Transformer.

Medium Voltage Distribution

Transformer Impedance

The Impedance of a Transformer is the ratio of transformer normal full load current to the current available under short circuit conditions.

Three phase full load current I_{FL} = Root 3xKVAX1000/ Voltage

Short Circuit Current $I_{sc} = I_{FL} / Z$

Where Z = Impedance

I_{FL} = Full Load Current

I_{SC} = Short Circuit Current

Medium Voltage Distribution Transmission

The Electricity transmission is done at different Voltages in different countries.

In Canada the transmission Voltages are 72kV, 138kV, 240kV, 500kV & 735kV. In US the max Transmission Voltage is 800kV.

The transmission network in US is 164,000 Miles Linking over 75,000 MW of Generation to Millions of customers by 3,000 Utilities

BCTC in Canada manages over 300 substations of transmission lines throughout the province of British Columbia .

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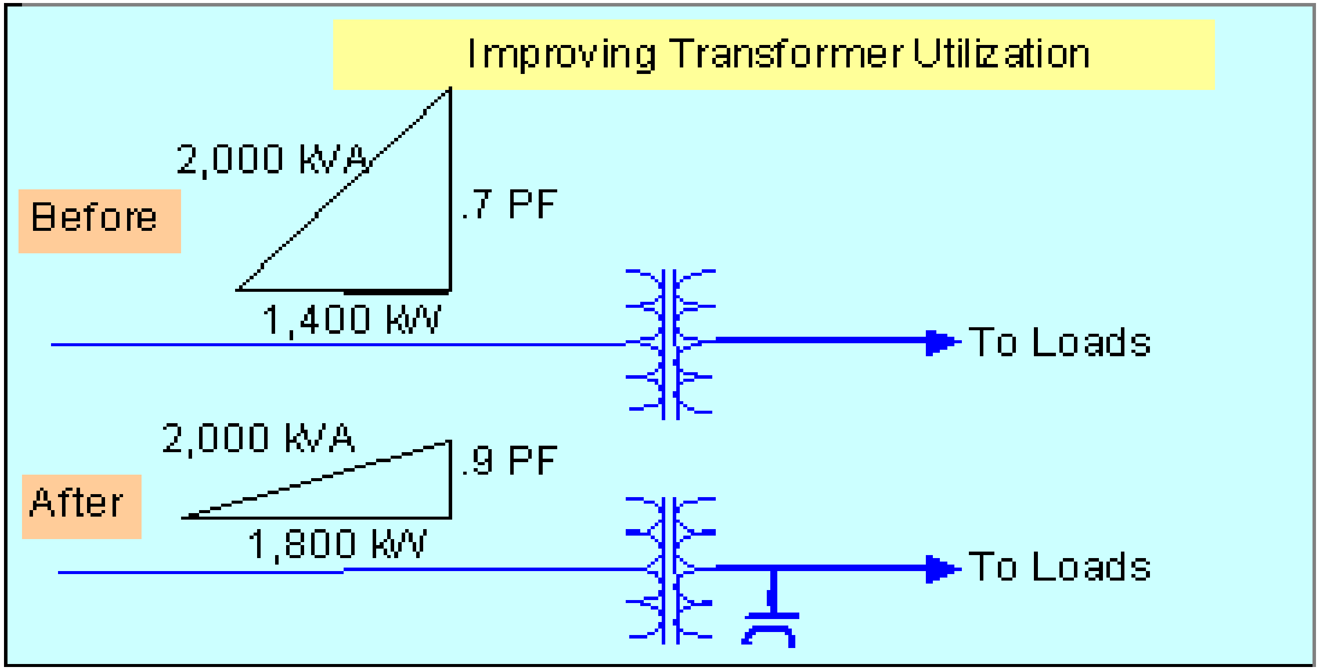
Medium Voltage Distribution
Power Factor

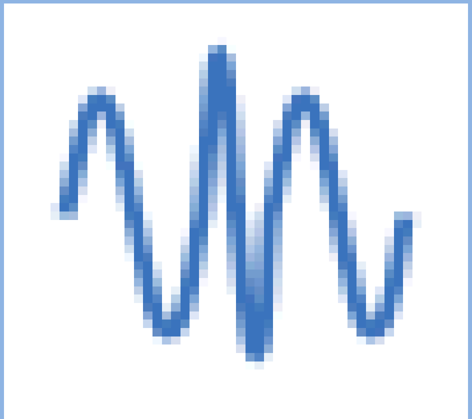
Power Factor: *Power factor compares the real power (watts) being consumed to the apparent power (Volts-Amps) of the load. A purely resistive load (incandescent lights, electric heating elements.) would have a power factor of 1.0. All current will cause losses in the supply and distribution system. A load with a power factor of 1.0 will result in the most efficient loading of the supply.*

Medium Voltage Distribution
Power Factor Improvement



Medium Voltage Distribution

Oscillations (resonances): The flow of electrical energy, e.g. between the magnetic field of an inductor and the electric field of a capacitor, changes direction periodically.

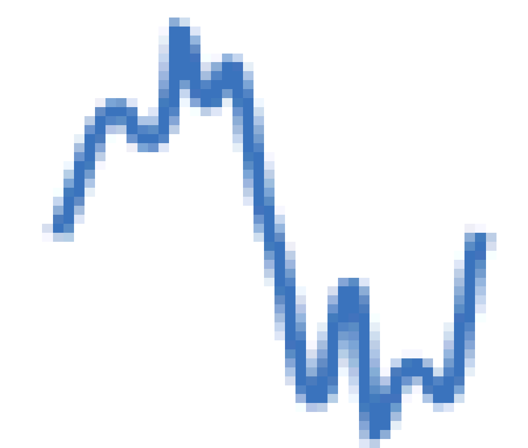


Reactive power:

The phase angle between the current and voltage waveforms in an AC system. Used to develop magnetic field in motors, causes low power factor.

<u>Flicker: Random or repetitive variations in the voltage.</u>

Caused by e.g. mills, EAF operation (arc furnaces), welding equipment and shredders.



<u>Voltage variations (dips, sags, swells, brown-outs):</u>

The line voltage is higher or lower than the nominal voltage for a shorter period. Caused by e.g. network faults, switching of capacitive loads and excessive loading.

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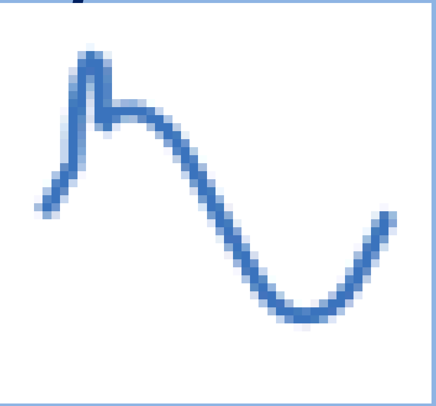
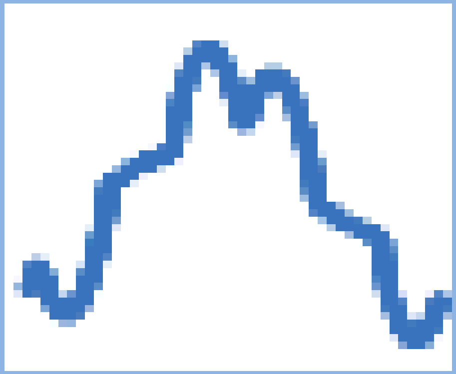
Transients (fast disturbances):

Rapid change in the sine wave that occurs in both voltage and current waveforms. Caused by switching devices, start- and stop of high power equipment.



Harmonics:

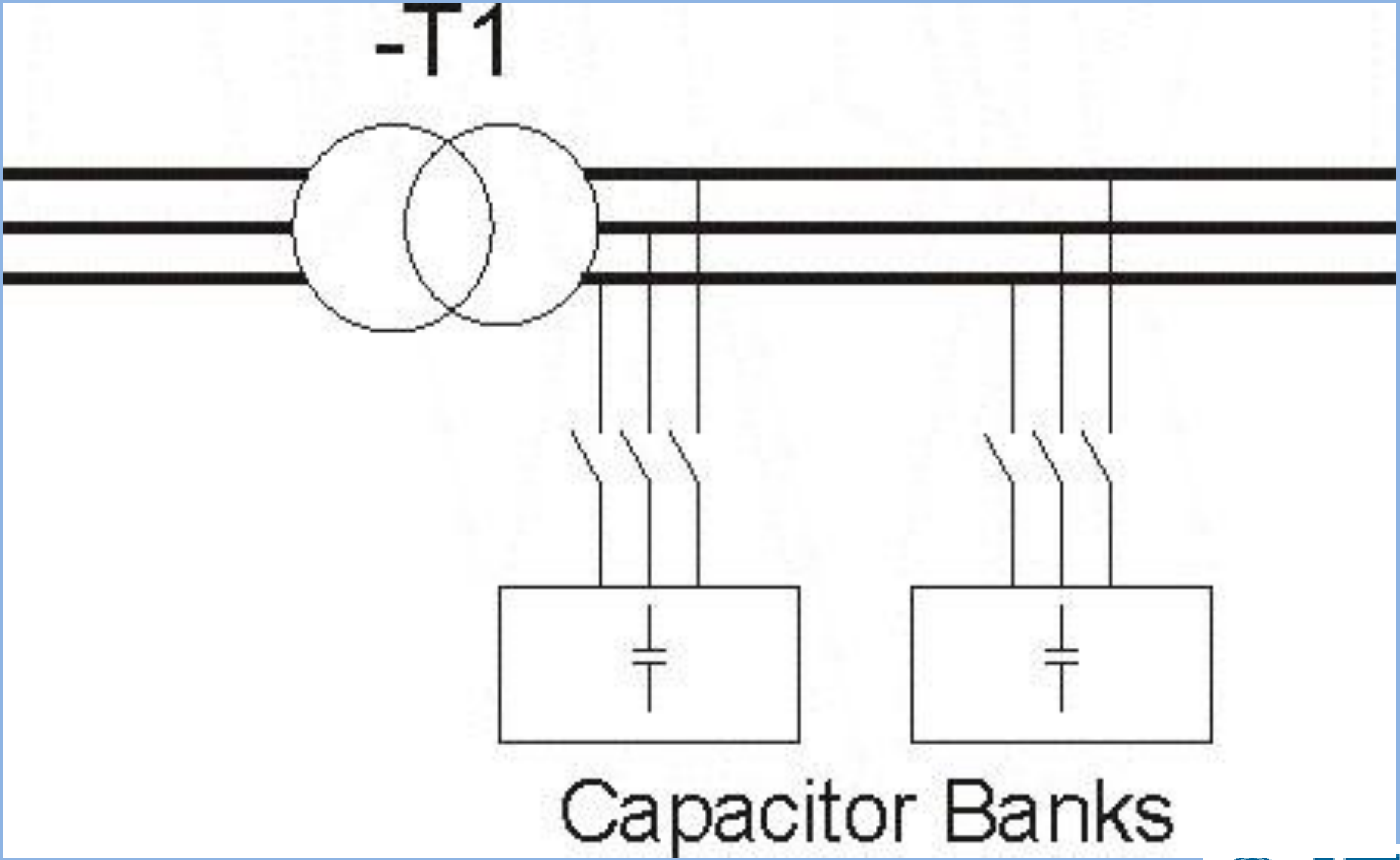
Multiples of the supply frequency, i.e. the fifth harmonic would be 250 Hz if the supply frequency is 50 Hz. Caused by e.g. power electronic loads such as variable speed drives and UPS systems.



Network unbalance:

Different line voltages. Caused by single-phase loads, phase to phase loads and unbalanced three-phase loads like welding equipment.

Medium Voltage Distribution
Power factor Improvement



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75MVar Capacitor Bank in 150kV Substation

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For Medium Voltage Distribution the primary Voltage Levels are 5kV, 15kV, 25kV & 35kV in Canada

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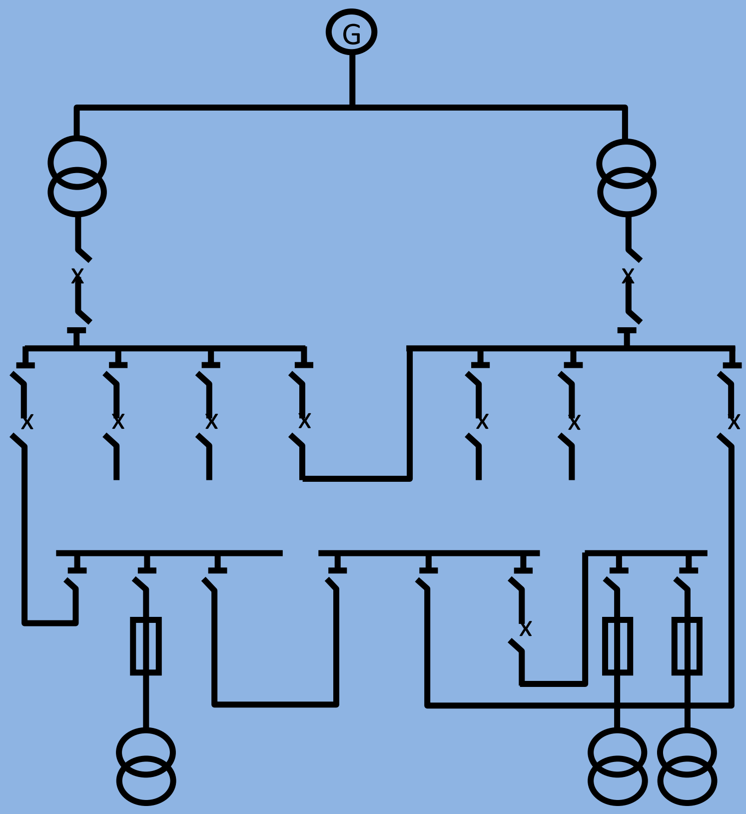
Medium Voltage Distribution

Generation level and high-voltage system

Primary distribution level

Secondary distribution level



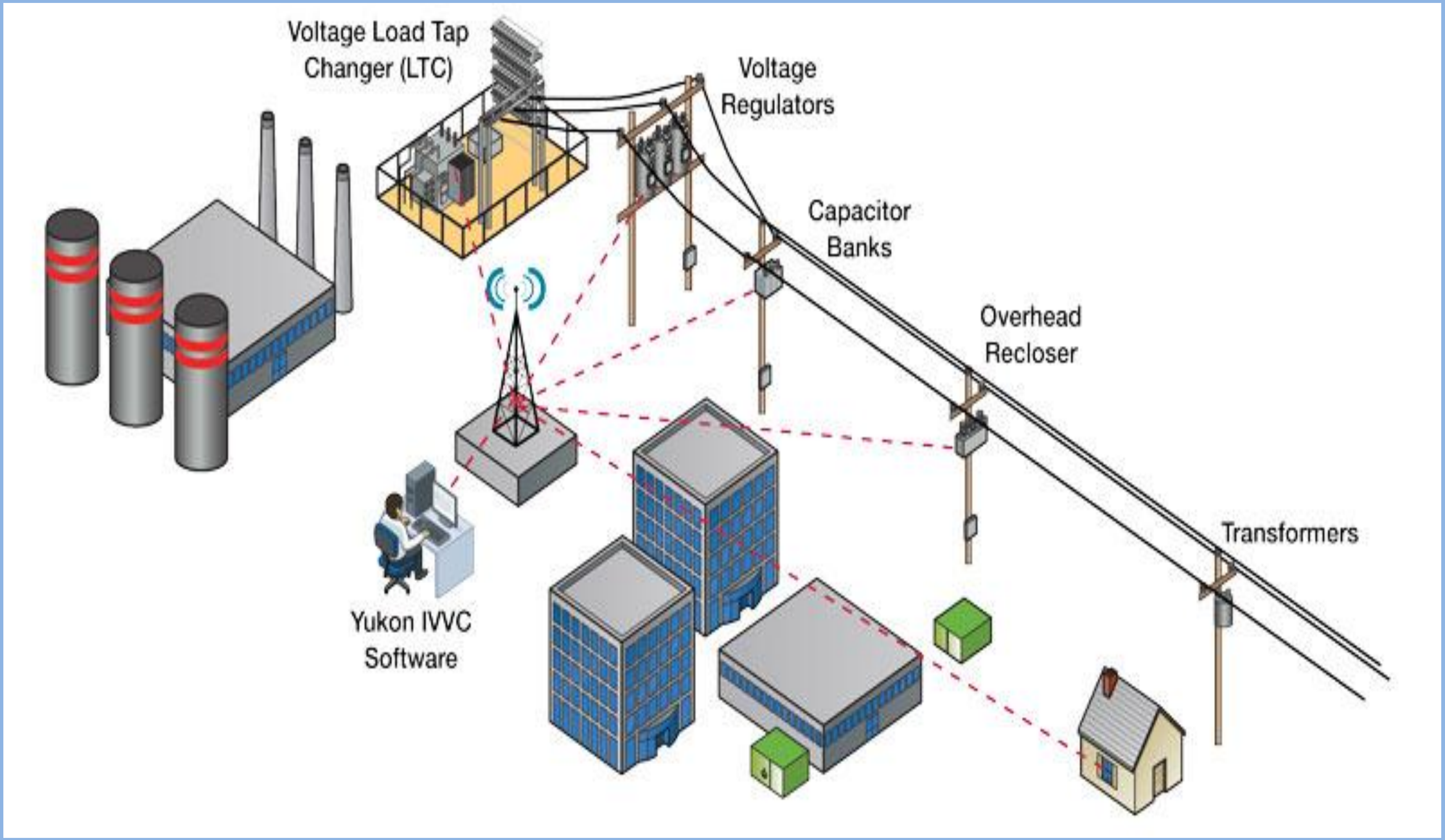
Medium Voltage Distribution

Utilities in Alberta are the following:

AltaLink
Enmax
ATCO
EPCOR
Utility of City of Red Deer
Utility of City of Medicine Hat
Utility if City of Lethbridge

***AltaLink, L.P. is one of Canada's largest transmission companies. Based in Alberta, AltaLink is maintaining and operating approximately 12,000 kilometers of transmission lines and 280 substations in Alberta*.**

Medium Voltage Distribution



Medium Voltage Distribution

Switchgear is designed to the Following Standards for North America

- ***ANSI/IEEE C37.20.2-1999 Metal-Clad Switchgear***
- ***ANSI/IEEE C37.04-1999 Standard Rating Structure for AC High-Voltage Circuit Breakers***
- ***ANSI/IEEE C37.06-2009 AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltages Above 1,000 Volts***
- ***ANSI/IEEE C37.09-1999 Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis***
- ***ANSI/IEEE C37.010-1999 Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis***
- ***ANSI/IEEE C37.20.7, Up To 50 kA, 0.5 sec, Accessibility Type 2B Arc-Resistant***

Medium Voltage Distribution

Both ANSI C84.1 and IEEE 141 divide system voltages into classes

VOLTAGE CLASS	VOLTAGE RANGE (AC)
Low voltage	Below 1,000 V
Medium voltage	1,000 V to 100 kV
High voltage	100 kV to 230 kV
Extra-high voltage	230 kV to 1,000 kV
Ultra-high voltage	Above 1,000 kV

Medium Voltage Distribution

The price of copper is increasing day by day. Over the past 10 years, the cost of copper has increased more than a 400% . As this cost continues to increase, contractors, design engineers, and facility owners are trying to find ways to reduce the amount of copper in the distribution system. One method is implementing medium-voltage distribution systems. In this case, the goal of using medium-voltage distribution is to move the transformation to utilization voltage closer to the load to take advantage of the reduced current at higher voltages. Lower current means smaller or fewer conductors to distribute power. Using smaller or fewer conductors decreases the amount of copper and therefore reduces cost. Conduit and installation costs are also lower.

Medium Voltage Distribution

Medium-voltage distribution helps to minimize voltage drop. The National Electrical Code (NEC) Article 215.2 recommends a voltage drop of 5% or less from the utility service to the load.

The larger the load current and the larger the conductor impedance, the larger the voltage drop.

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Medium Voltage Distribution

Today about 80 percent of power network operators decide in favor of vacuum switching technology

The market share of vacuum circuit-breakers is more than 99 % in Germany.

The core component of this switching principle is the vacuum interrupter.

Medium Voltage Distribution
Vacuum Interrupters

Circuit breakers must make and break all currents within the scope of their ratings, from small inductive and capacitive load currents up to the short-circuit current, and this under all fault conditions in the power supply system such as earth faults, phase opposition and so on.

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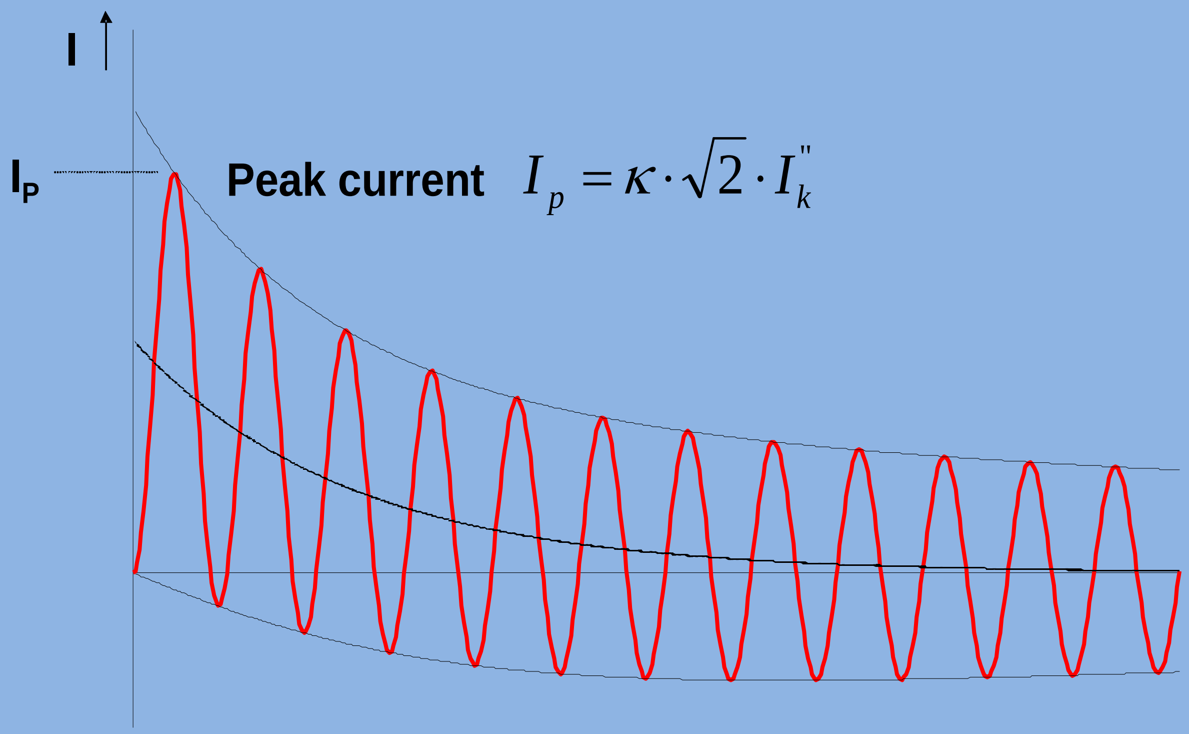
Rated peak and/or making current



IEEE: ***I_{ma} or I_P = 2,6 · I_k at 60 Hz***

IEC: ***I_{ma} or I_P = 2,5 · I_k at 50 Hz***

2,6 · I_k at 60 Hz

2,7 · I_k at 50 Hz if ratio X/R > 14 (i.e. τ > 45 ms)

Medium Voltage Distribution

The decisive advantage of the vacuum interrupter is that its properties remain constant throughout the entire life cycle, due to the hermetically tight vacuum interrupter which eliminates any external influences

Medium Voltage Distribution

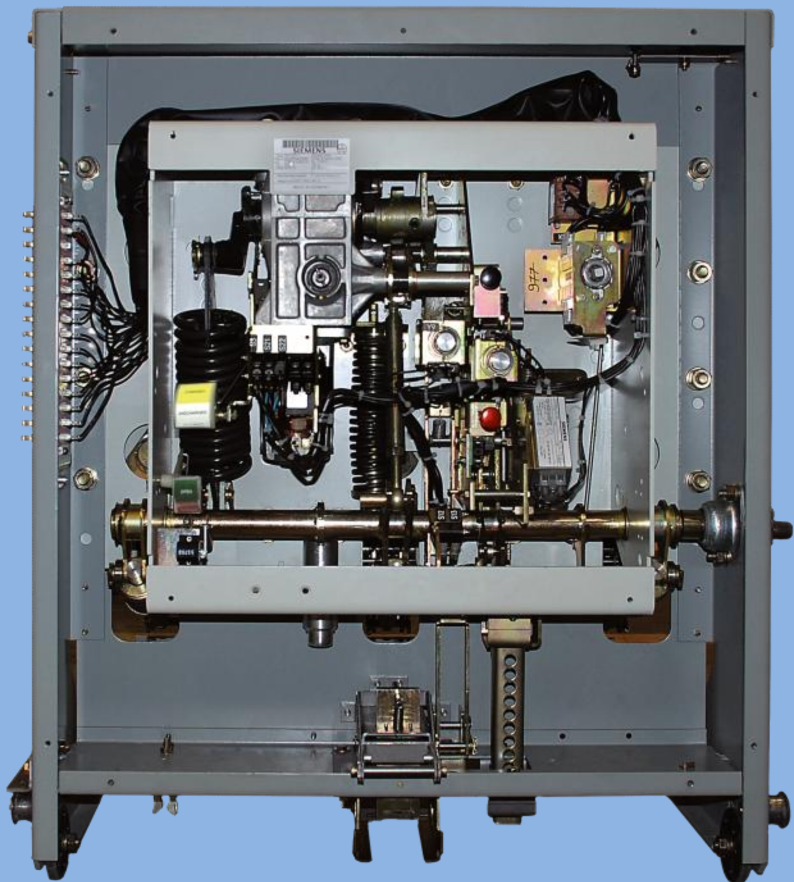
Medium Voltage Breaker Operating Mechanism

The Breaker operating Mechanism for

- **5-cycle interrupting time (standard)**
- **3-cycle interrupting time (optional)**

1,200 A-3,000 A continuous current (self-cooled)

Up to 4,000 A continuous current with fan-cooling in cubicle.



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Medium Voltage Distribution
Medium Voltage Circuit Breaker

Rating interlock (universal spare circuit breaker)*
Rated for 10,000 operations prior to maintenance
Up to 100 full-fault operations (depending upon rating)
Spring-loaded fingers for secondary disconnect
Outer phase barriers for easy access
**** Circuit breaker fits any cell up to 50 kA provided rated voltage, continuous current and interrupting current equal or exceed requirements of the cell***

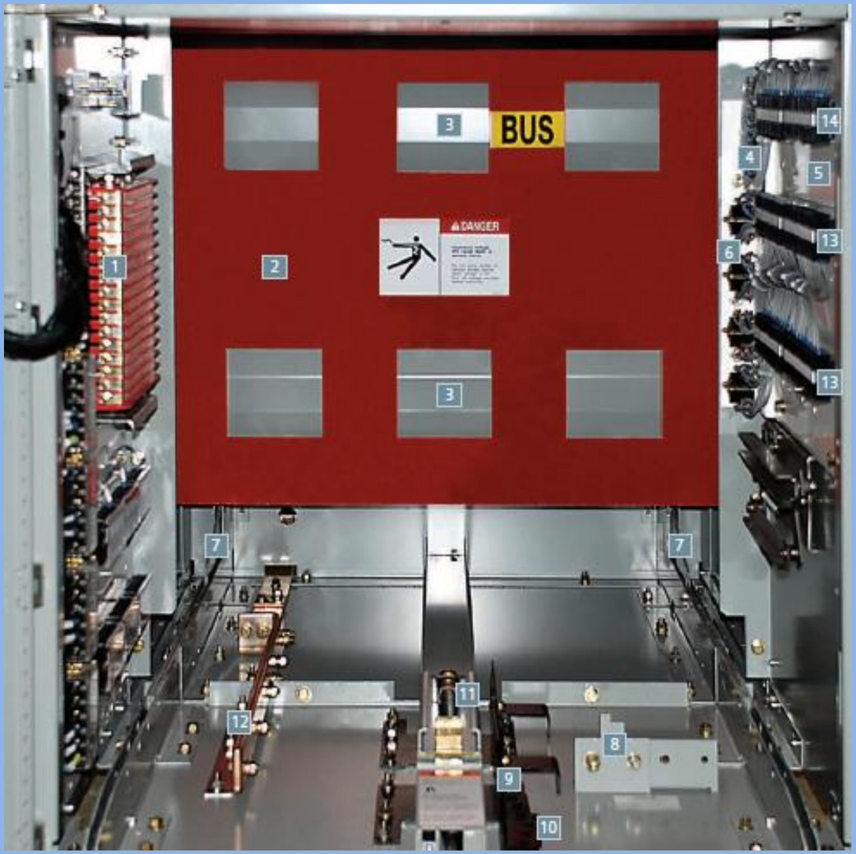
1	Manual spring-charging access port
2	Manual close button
3	Charged/discharged indicator
4	Open/closed indicator
5	Operations counter
6	Manual open/trip button

Medium Voltage Distribution

Medium Voltage Circuit Breaker Racking mechanism

- *White interior device panels improve visibility*
- *Floor-mounted racking mechanism*
- *Glass-polyester CT safety barrier*
- *Secondary disconnects automatically engage in both TEST & CONNECTED positions*

1. Secondary disconnect
2. Current transformer barrier
3. Shutters, primary disconnects & current transformers (behind shutters)
4. Truck-operated cell switch (TOC) (optional)
5. White interior device panel
6. Mechanism-operated cell switch (MOC) (optional) (cover removed for photo)
7. Shutter operating linkage
8. Ratings interlock
9. Trip-free padlock provisions
10. Racking mechanism padlock provisions
11. Racking mechanism
12. Ground bar
13. MOC terminal blocks
14. TOC terminal blocks



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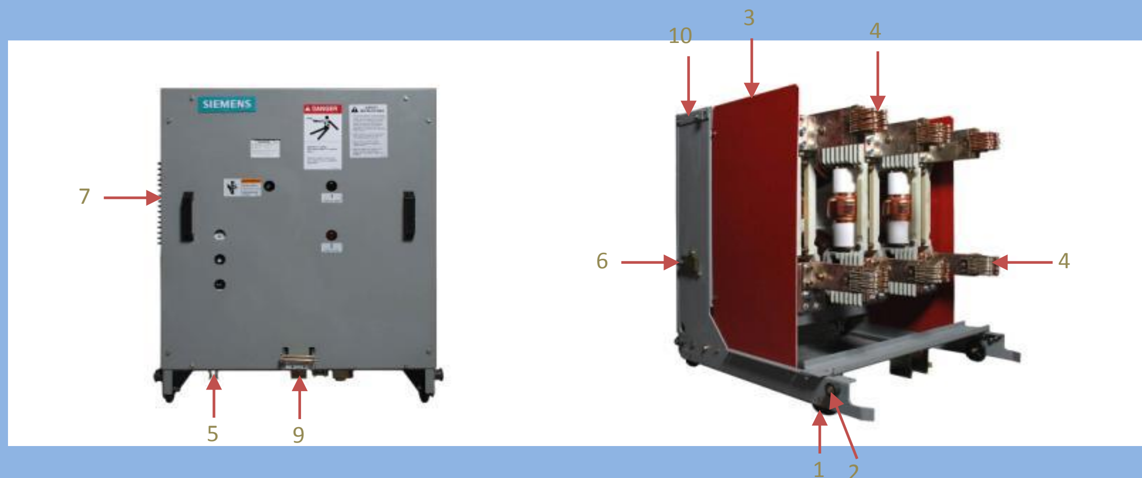
MV Circuit Breakers for AIS



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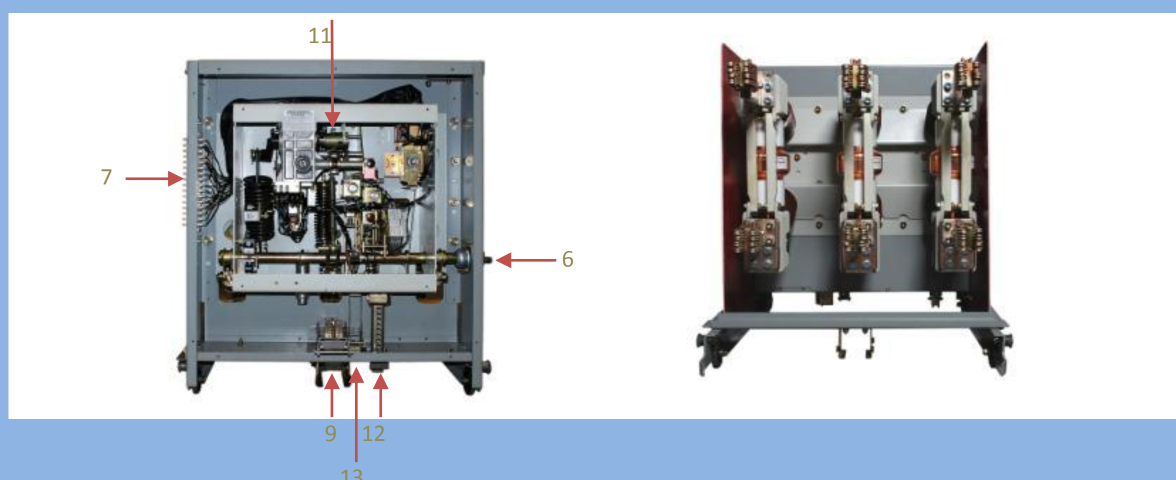

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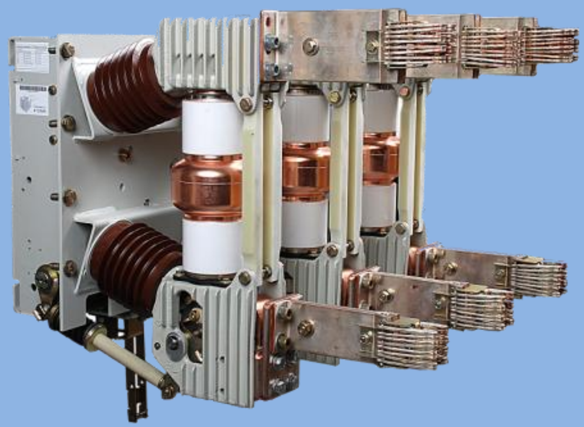
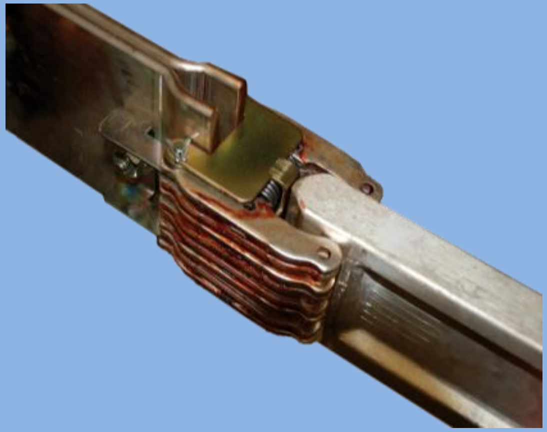
Medium Voltage Distribution
MV Circuit Breakers





Finger Cluster

Compatible configuration for all ratings enables universal spare concept

1” uniform gap between fingers for all ratings enables universal spare concept (up to 50 kA)

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Air Insulated Switchgear

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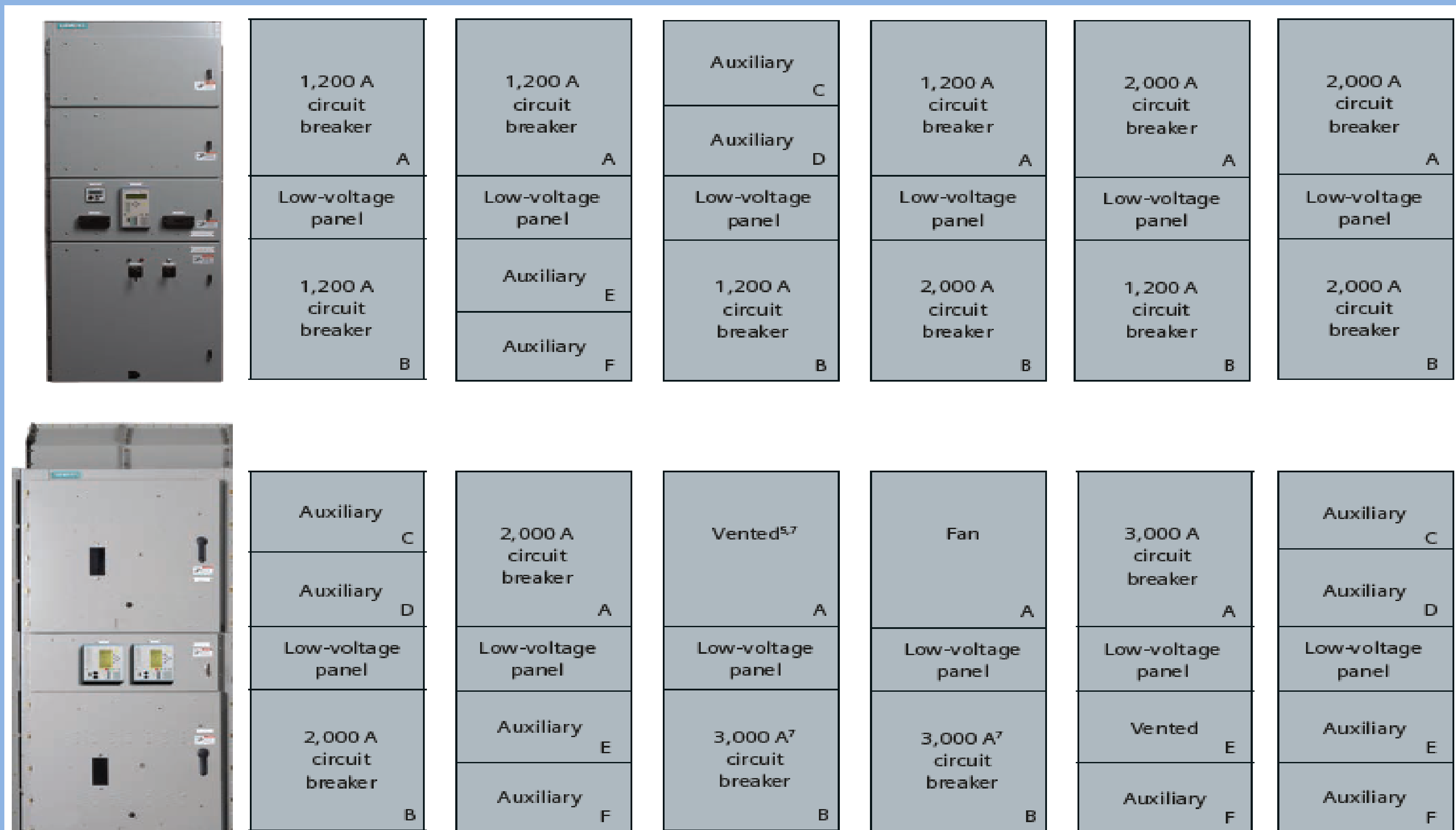
Medium Voltage Distribution
Medium Voltage Switchgear Panel arrangements



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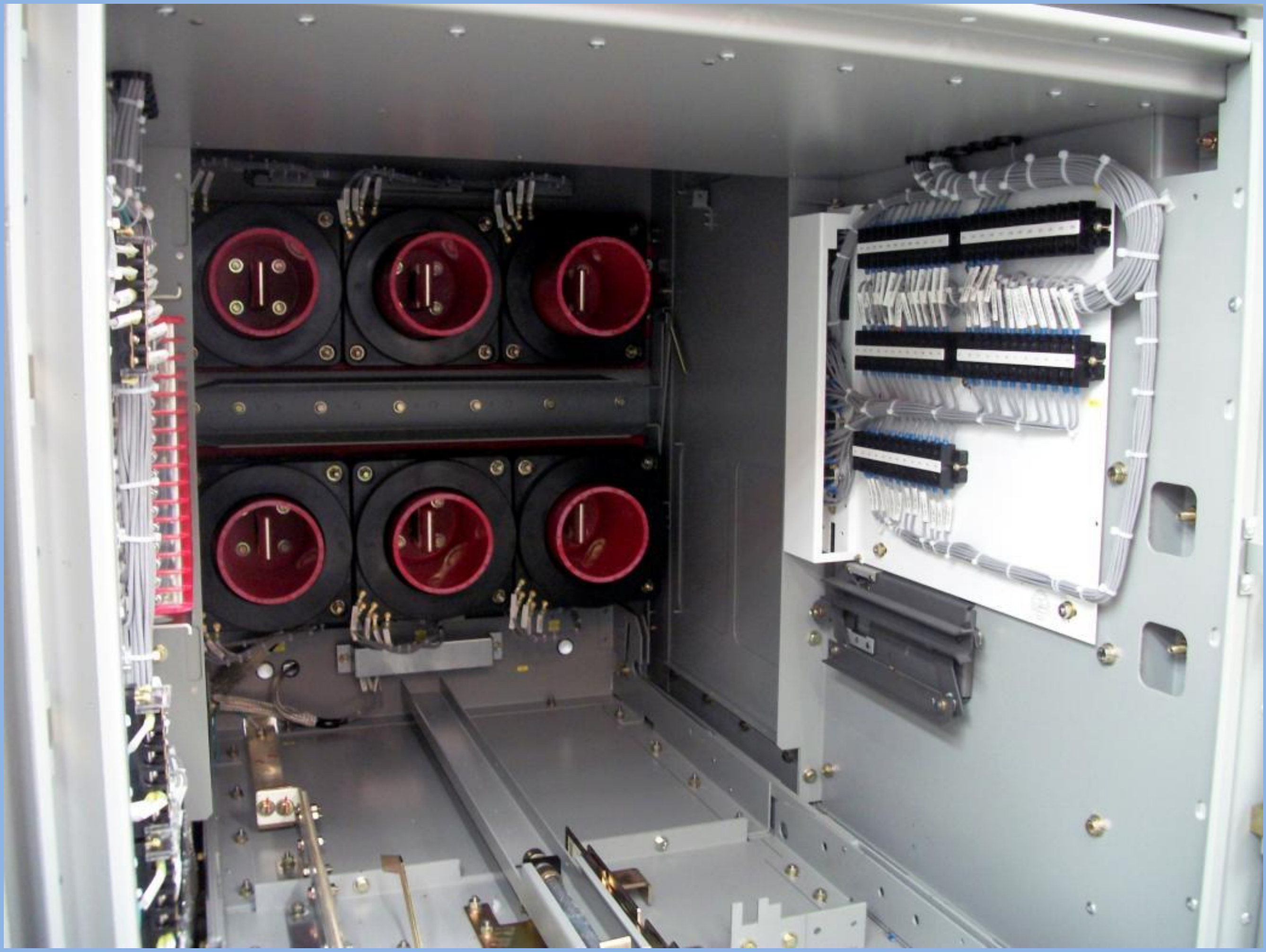
Medium Voltage Distribution

Medium Voltage Circuit Breaker racking mechanism

TOC switches & TOC terminal blocks
MOC switches & MOC terminal block
Secondary customer terminal blocks
Secondary wire guard



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Medium Voltage Distribution

Medium Voltage Air Insulated Switchgear

5 kV, 7.2 kV & 15 kV
rated metal-clad switchgear
25 kA, 40 kA, 50 kA & 63 kA
interrupting ratings
1,200 A, 2,000 A, 3,000 A & 4,000 A main
bus ratings (self-cooled)
1,200 A, 2,000 A & 3,000 A (self-cooled)
plus 4,000 A fan-cooled circuit breaker
ratings
5-cycle interrupting time (standard)
3-cycle interrupting time (optional)
Universal spare circuit breaker up to 50
kA & lower ratings
Universal spare circuit breaker for
63 kA ratings

Medium Voltage Distribution
Medium Voltage Arc Resistant Switchgear

5 kV, 7.2 kV & 15 kV rated metal-clad switchgear
25 kA, 40 kA & 50 kA interrupting ratings
1,200 A, 2,000 A, 3,000 A & 4,000 A main bus ratings (self-cooled)
1,200 A, 2,000 A & 3,000 A (self-cooled) plus 4,000 A fan-cooled circuit breaker ratings
5-cycle interrupting time (standard)
3-cycle interrupting time (optional)
Universal spare circuit breaker up to 50 kA & lower ratings

Arc Resistant to ANSI/IEEE C37.20.7, Up To 50 kA, 0.5 sec, Accessibility Type 2B

Medium Voltage Distribution

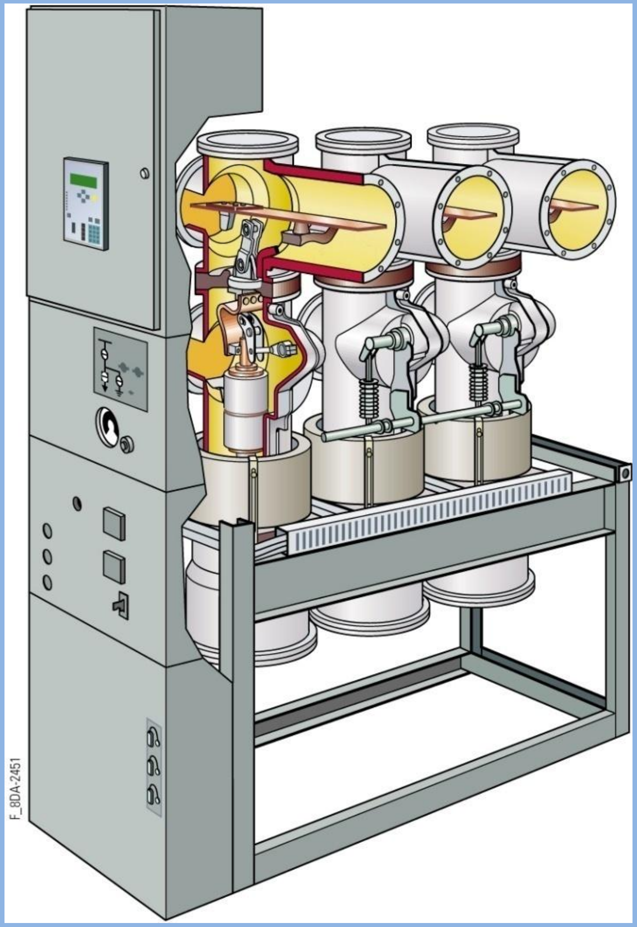
Medium Voltage Gas Insulated Switchgear Switchgear

Today's state of the art is gas-insulated switchgear with the following main benefits:

- *Small, compact dimensions*
- *Independent of environmental effects and climate*
- *Widely maintenance-free*
- *Maximum safety for staff*
- *Low fire risk*
- *Arc-fault tested*

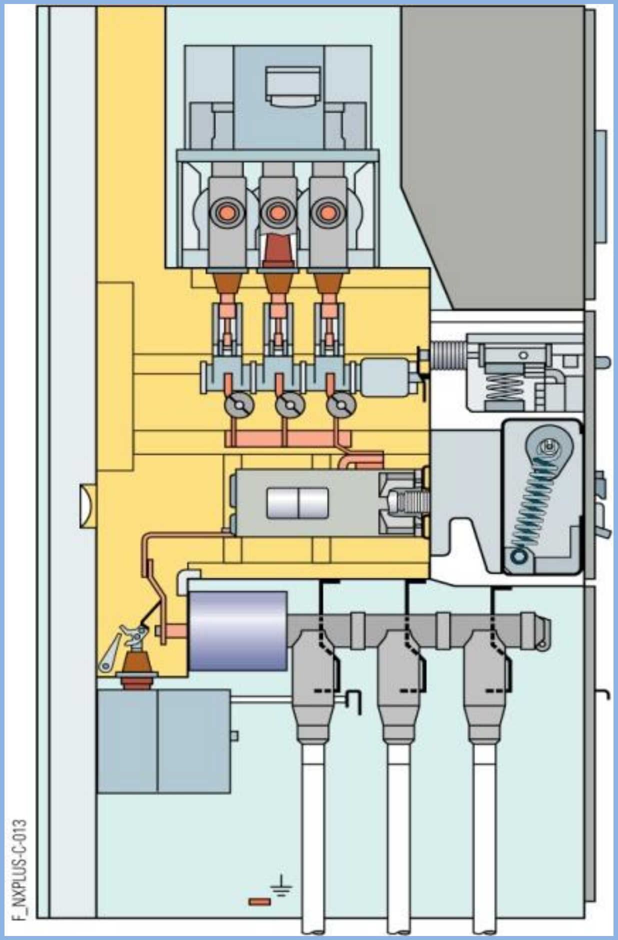
Advantages:

- *Low invest for buildings due to compact dimensions and climate-independent design*
- *Maximized power supply reliability*
- *Maximum personal safety*
- *Lowest life cycle costs*
- *Reduced operational costs*

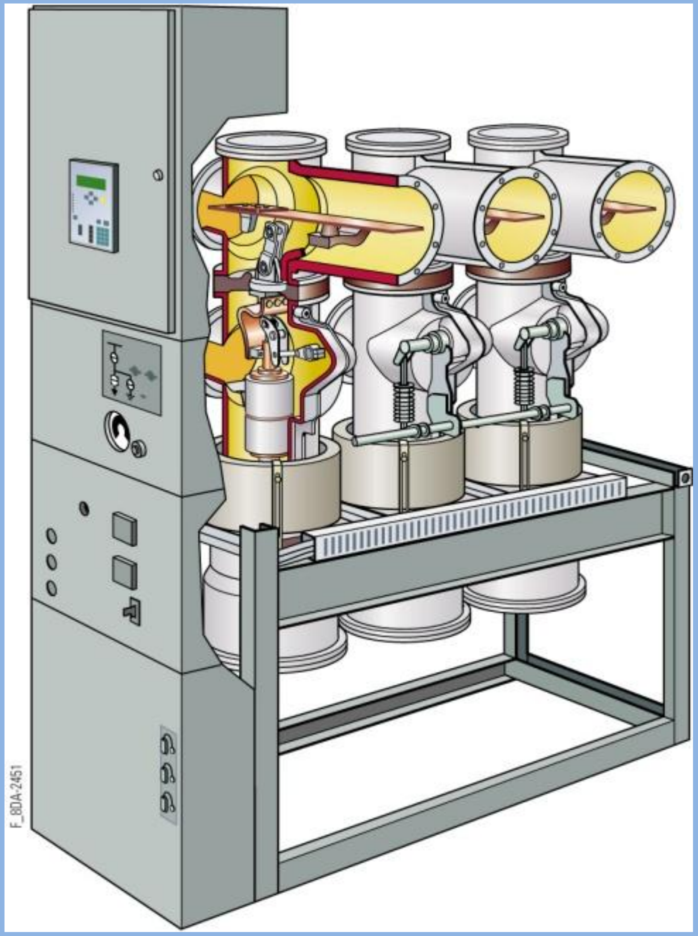


Medium Voltage Distribution
Medium Voltage Gas Insulated Switchgear

Three phase encapsulation

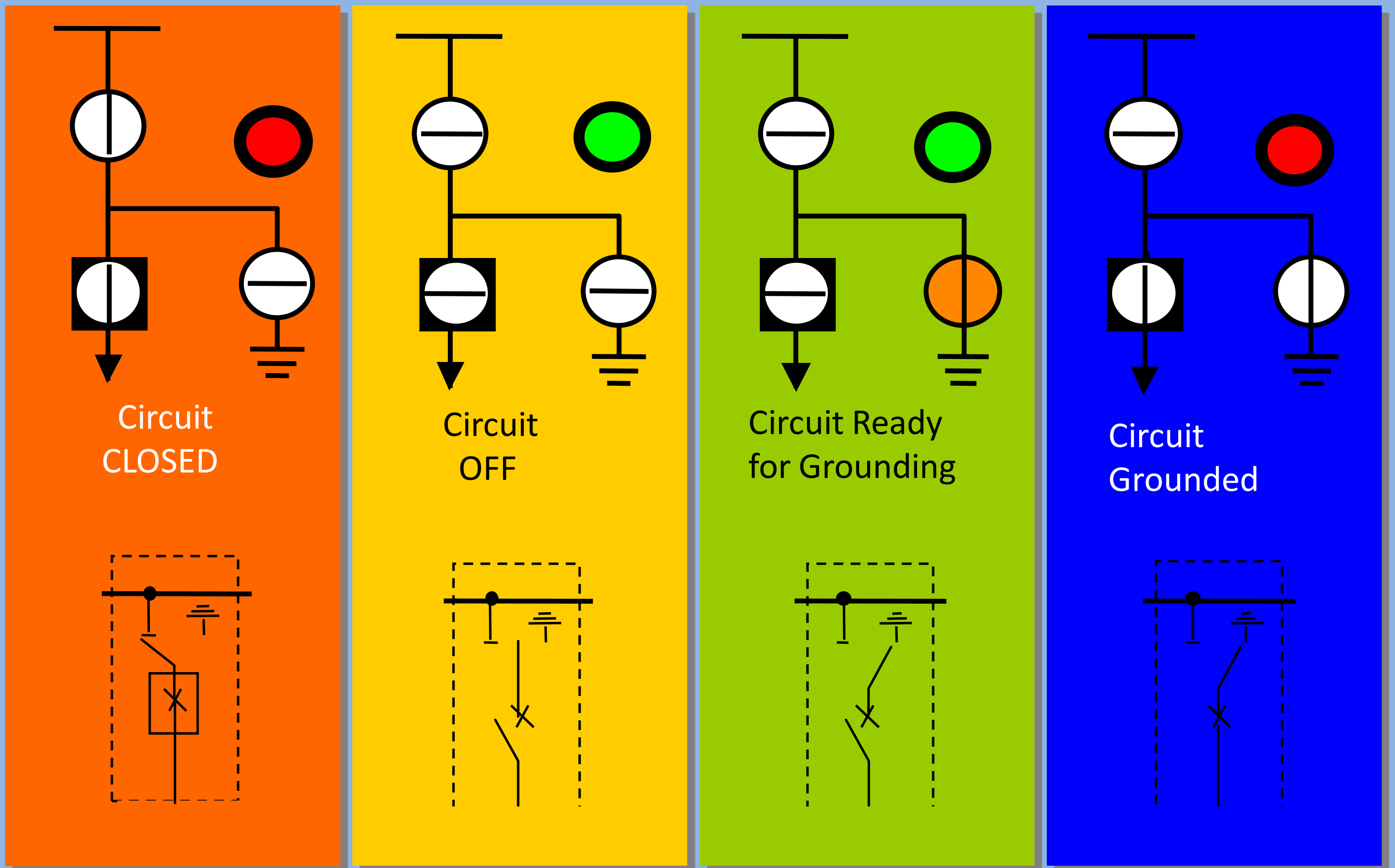


Single Phase encapsulation
(W600mmxD1625mmxH2350mm)



Medium Voltage Distribution

Medium Voltage GIS Mode of operation
The role of Three Position Selector Switch



Medium Voltage Distribution
Medium Voltage GIS

GIS is Arc Fault Tested
AS PER ANSI 37.20.7-2007
(Personal Protective Equipment)
PPE Level required is HRC0

September 21, 2015 Sharif Ahmed
Senior Member IEEE

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For Major Operational Activities,

Reduced Level Of PPE Can Be Used For MV GIS

- Comparison of PPE[3] level required for operations

Activity	MV Air-Insulated Switchgear (AIS)[1]	MV GIS
Open/close circuit breaker	HRC 2 (door closed)[2] HRC 4 (door open)	HRC 0
Isolate circuit	HRC 4 (racking, door open or closed) (Note: isolation in metal-clad requires racking to test or disconnect position)	HRC 0 (operation of three-position switch to open position)
Application of safety grounds	HRC 4	HRC 0

Medium Voltage Distribution

A Closer Look at GIS vs AIS

Much smaller in size

GIS

Requires 20%
of space needed
for air- insulated
designs

Medium Voltage Distribution
MV Outdoor Breakers
These outdoor Breakers are used in remote places for MV Distribution

Small footprint

Arc-resistant option, accessibility type 2B

Full range of ratings

15 kV - 38 kV

20 kA - 40 kA

1,200 A - 3,000 A

Available with stored-energy or magnetic-actuator operator

Complete ANSI/IEEE type-testing program

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Questions

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References

-Wikipedia

-Siemens Publications

-Consulting specifying Engineers

-Work nuclear Association