Module 1: Main Components of Power Systems

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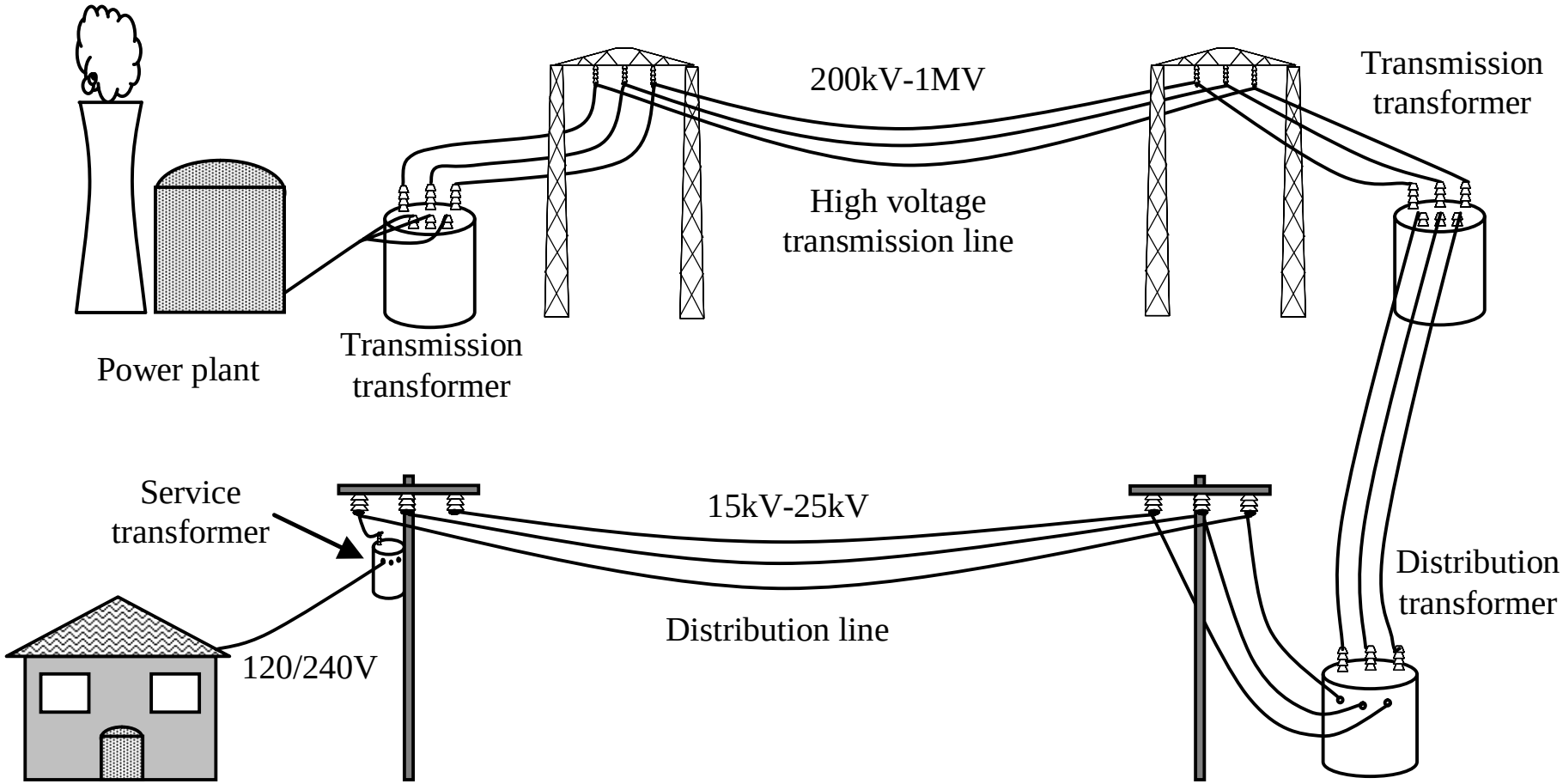

200kV-1MV
Transmission transformer
High voltage transmission line
Power plant
Transmission transformer
Service transformer
15kV-25kV
Distribution transformer
Distribution line
120/240V

Worldwide Standard for Voltage and Frequency

Country	**Voltage (V)**	**Frequency (Hz)**
Brazil	110/220	60
Canada	120	60
China	220	50
Egypt	220	50
United Kingdom	230	50
United States of America	120	60
Japan	100	50/60

Why different Voltage standards?

- 120 V was chosen somewhat arbitrarily in the USA.
  - Thomas Edison came up with a high-resistance lamp filament that operated well at 120 V.
- Generally, a wire is less expensive when the voltage is high
  - the cross section of the copper wires is smaller for higher voltages.
- Lower voltage circuits are safer than the high voltage ones
  - 100V is perceived to be less harmful than 240V.

Why different Frequency standards?

- In Europe, Siemens and AEG have established the 50Hz as a standard for their power grid.
- Most of Asia, parts of South America, all Africa, and the Middle East have adopted the same 50Hz standard.
- In the USA, Westinghouse adopted the 60Hz standard.
  - 60 Hz is high enough frequency to eliminate light flickers in certain types of incandescent lamps
  - 60 Hz is conveniently synchronized with time
  - Machines designed for 60 Hz can have less iron and smaller magnetic circuits than the ones designed for 50 Hz.

Main Components of PS

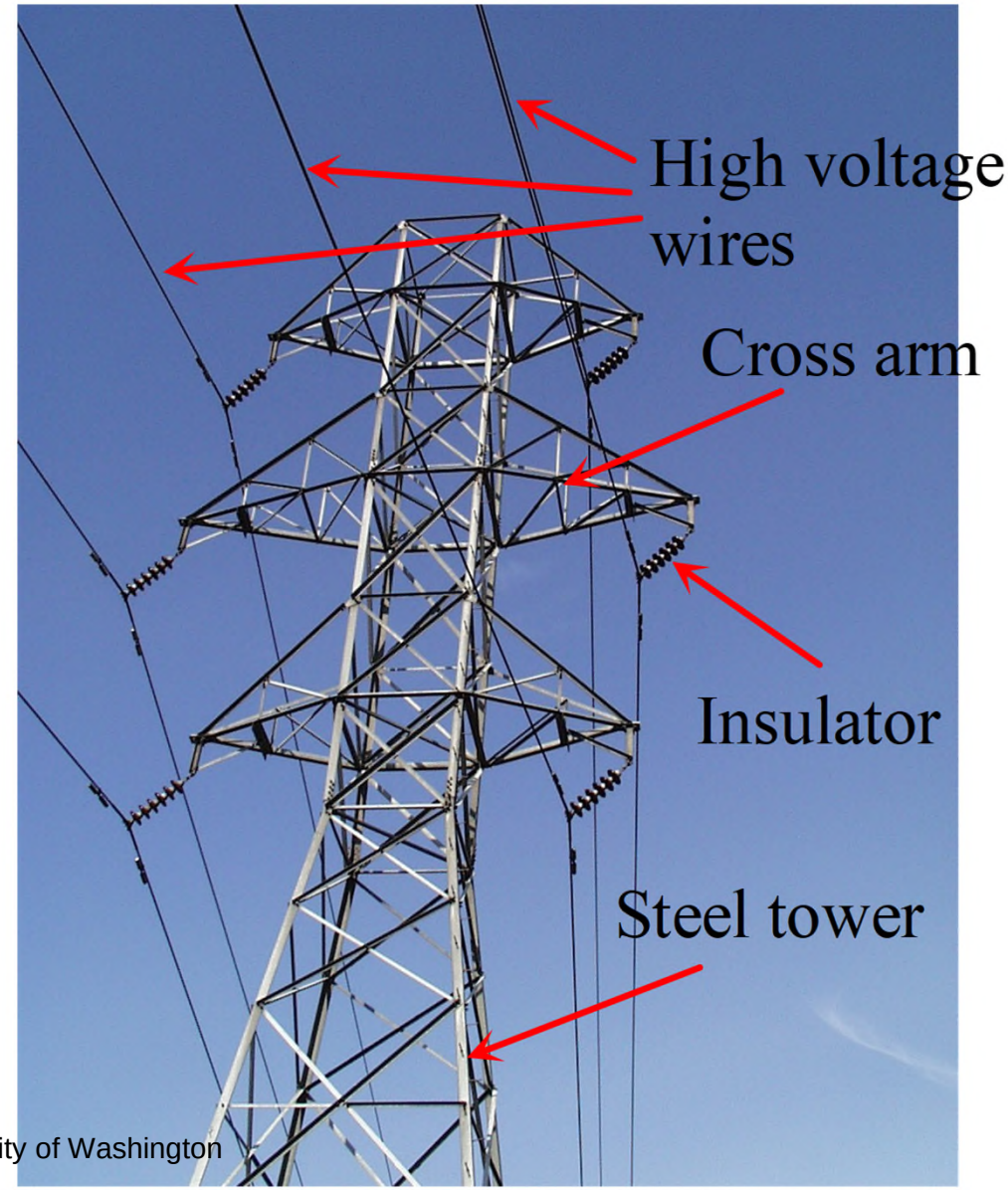
- Power Plant
  - Turbine
  - Generator
- Transformers
- Transmission Lines
- Distribution Lines
- Protection and Control

Nuclear Power Plant

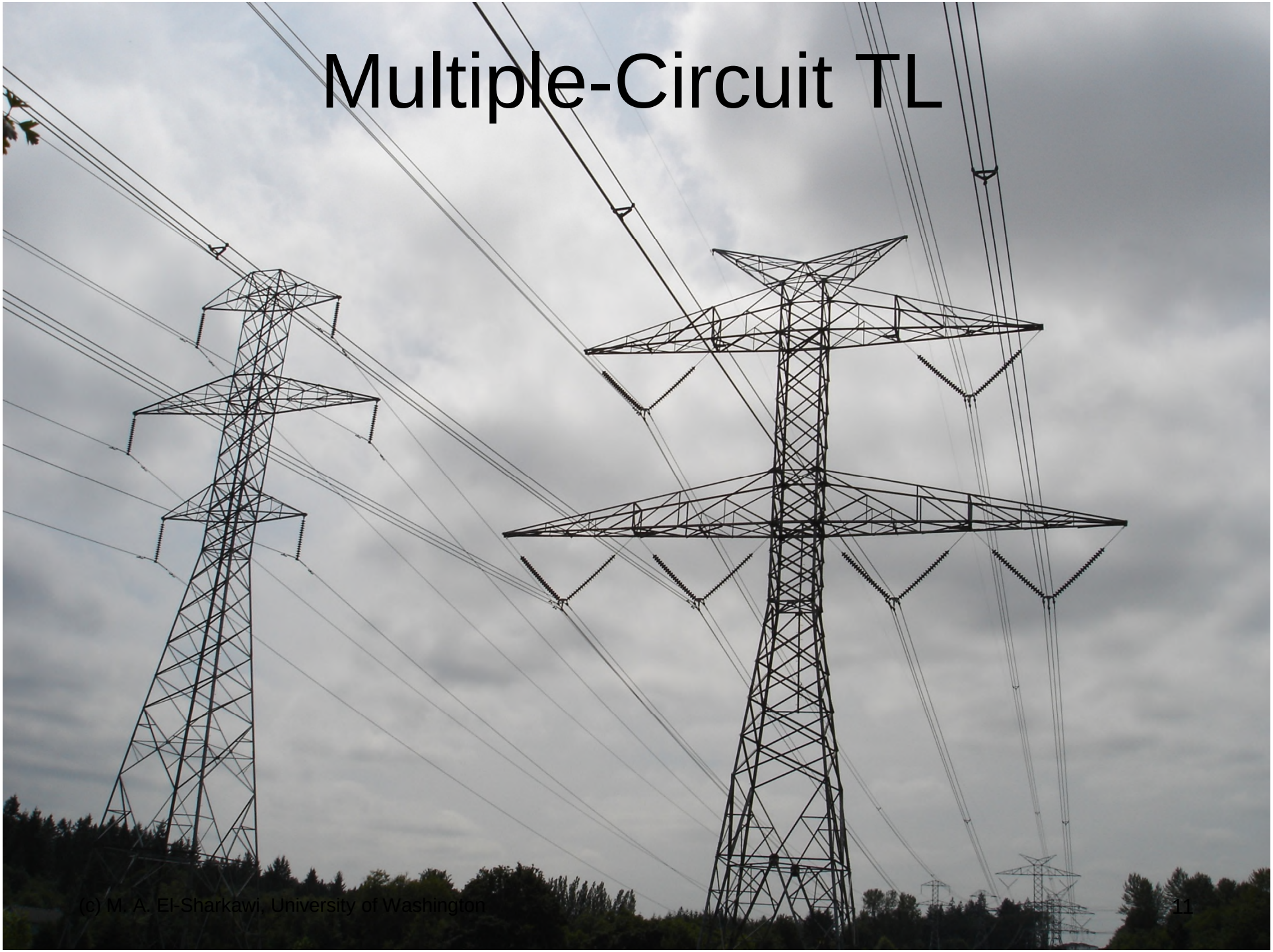
Hydroelectric Power Plant

Thermal Power Plant

Transmission Line

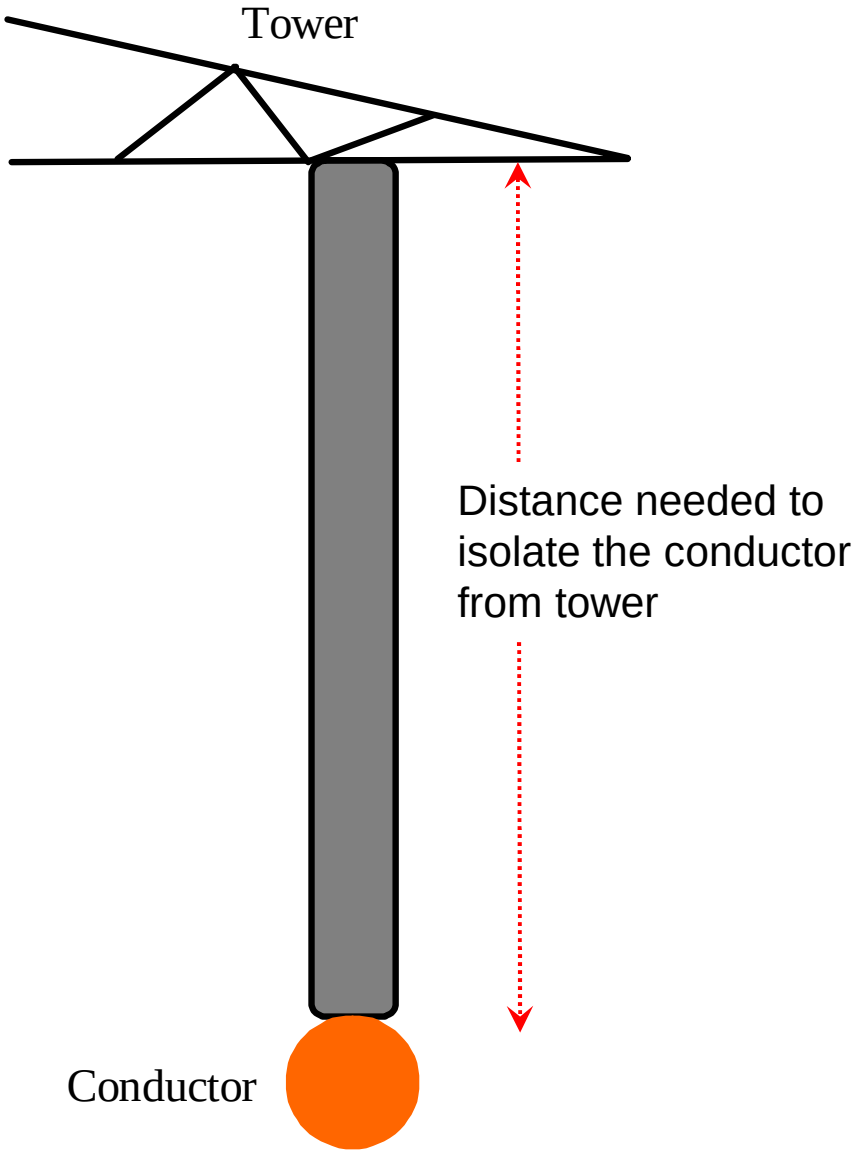


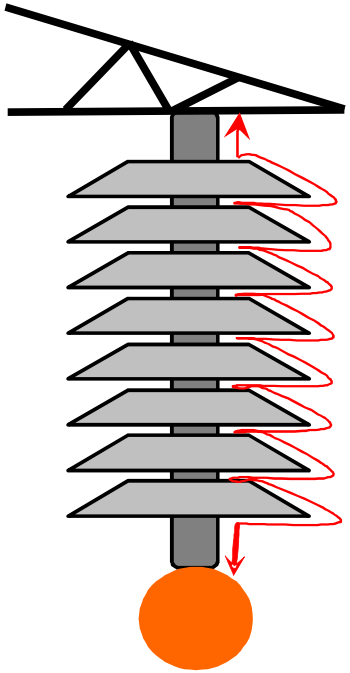
Multiple-Circuit TL



Insulator

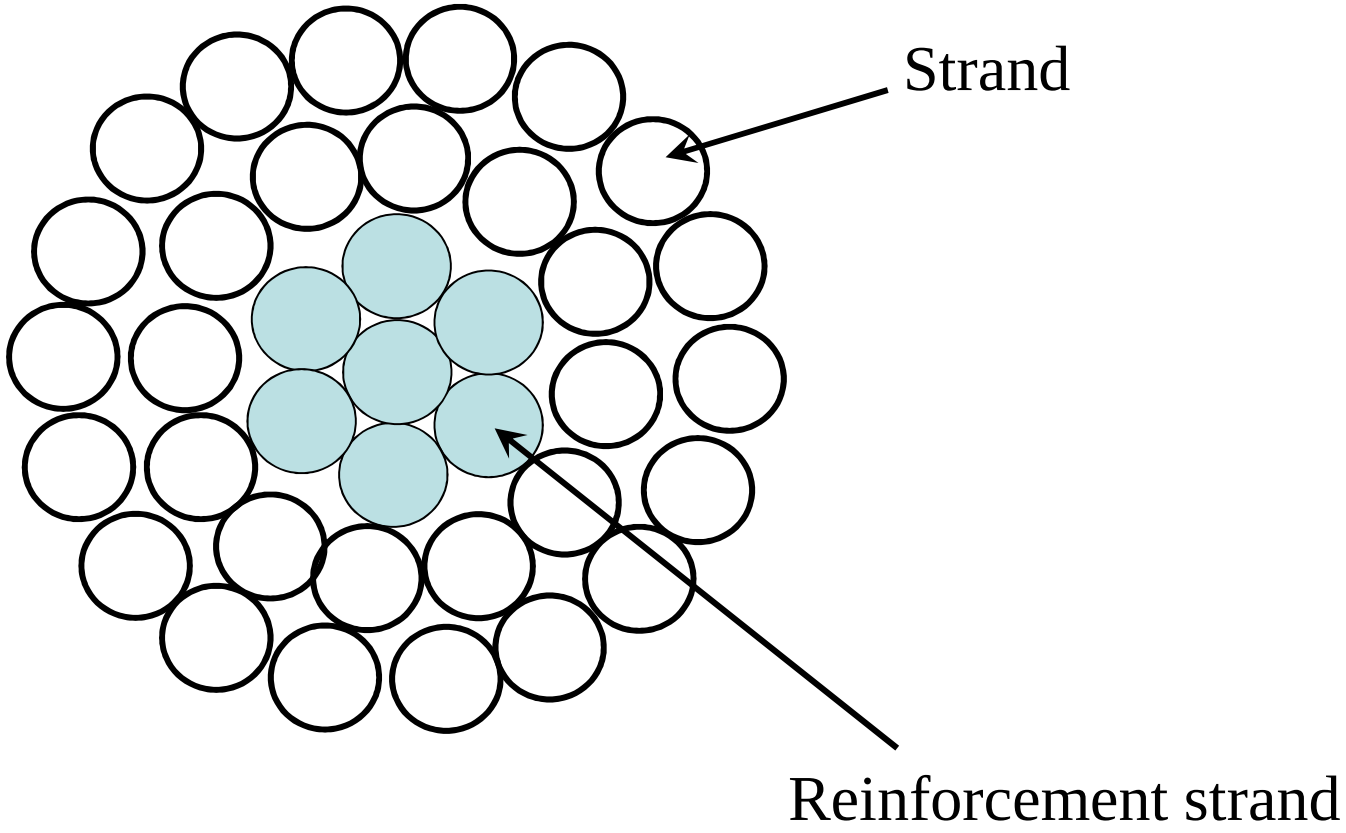
Why do we use Desk Shaped Insulators?





Same surface distance between the conductor and tower (creepage distance). But smaller vertical length of insulator

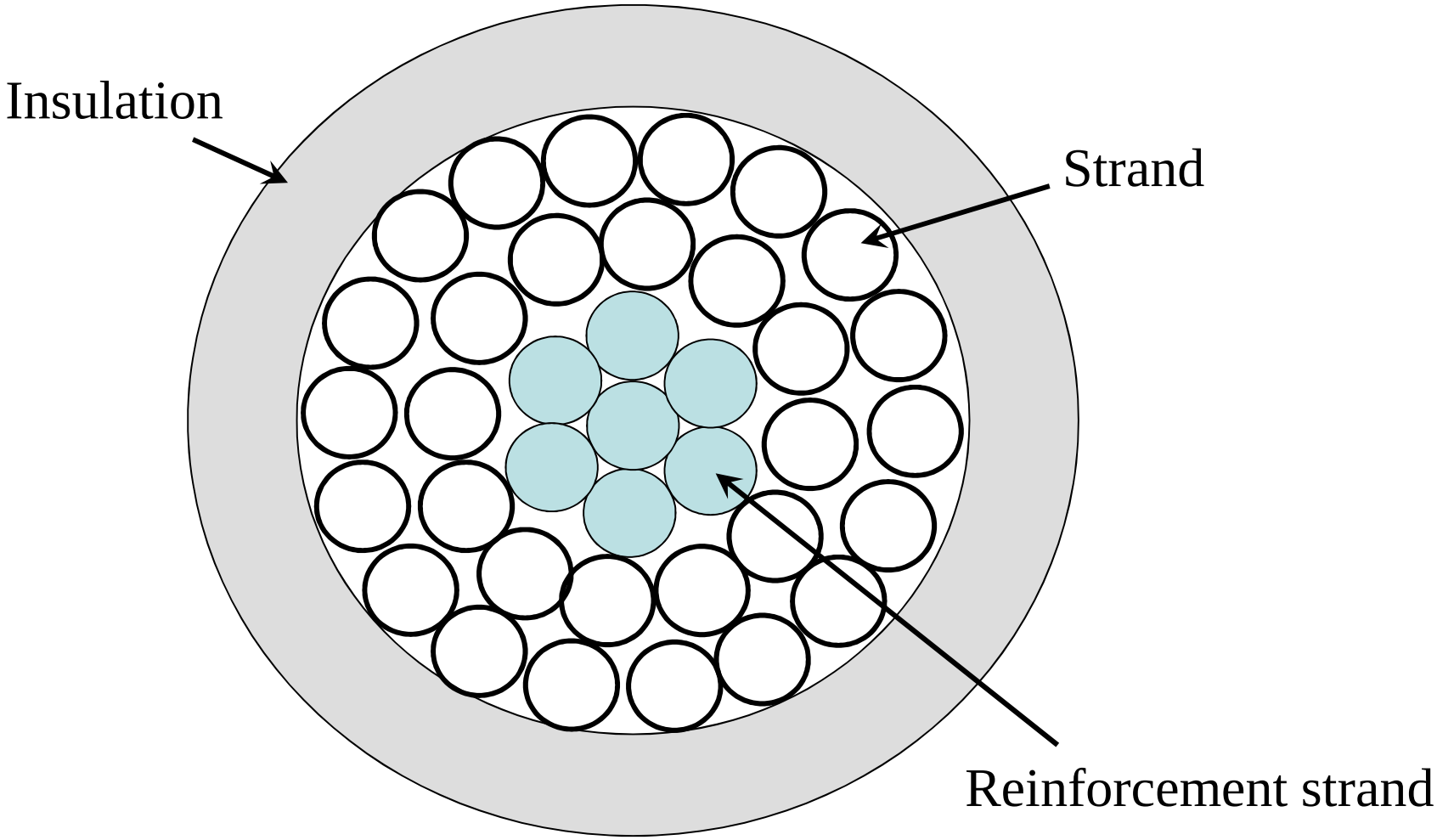
TL Stranded Conductor



Stranded Conductors

- Strands are used to provide flexibility
- Reinforcement are used to provide strength and ruggedness
- The layers of a stranded conductor are spiraled in opposite directions to prevent unwinding.

Stranded Cable



Bundled Conductors

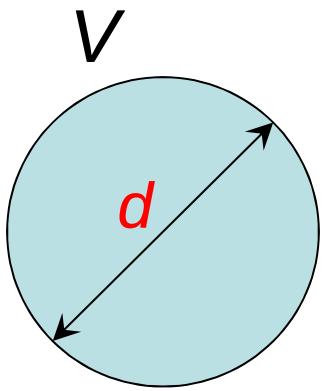
Why Using Bundled Conductors?

- High voltage conductors ionize air around them.
- Ionization produces corona; a form of leakage current
  - Energy losses
  - Wide frequency spectrum that interferes with wired and wireless communications
  - Damage conductors

Why Using Bundled Conductors?

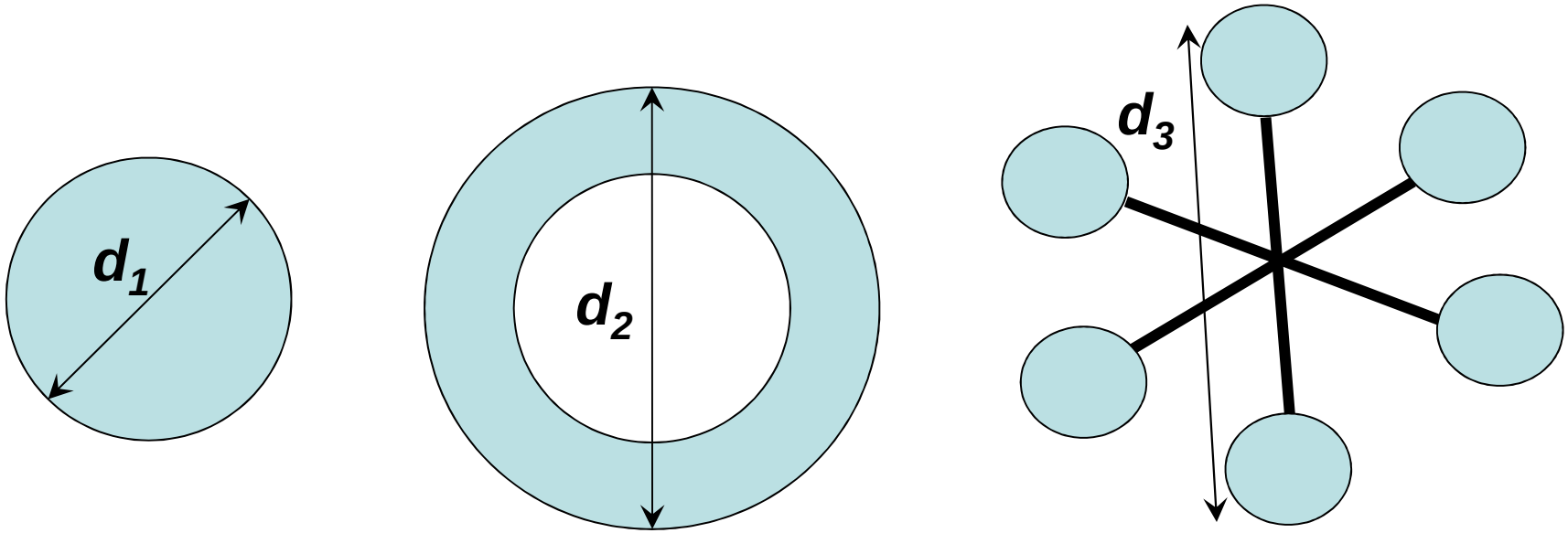
- Corona is proportional to the electric field strength (E) at the surface of the conductor.

$$E = \frac{V}{d}$$



Conductor

Bundled Conductors



Area 1

Area 2

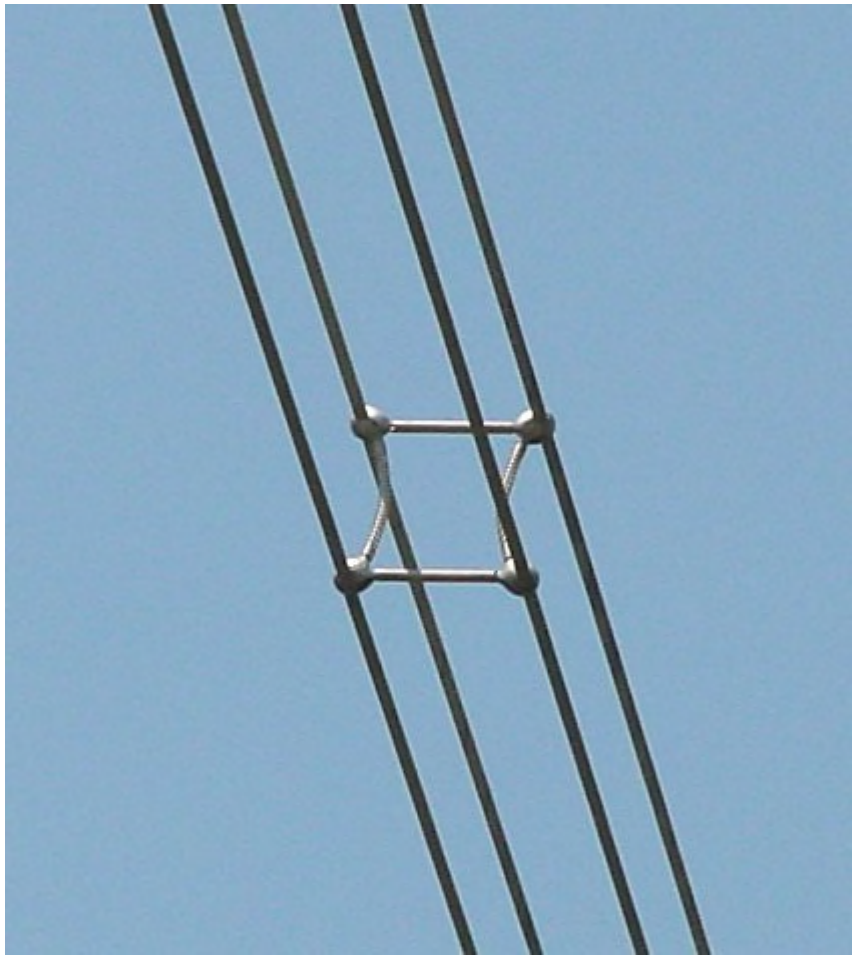
Area 3

Area 1 = Area 2 = Area 3

Diameter 1 < Diameter 2 < Diameter 3

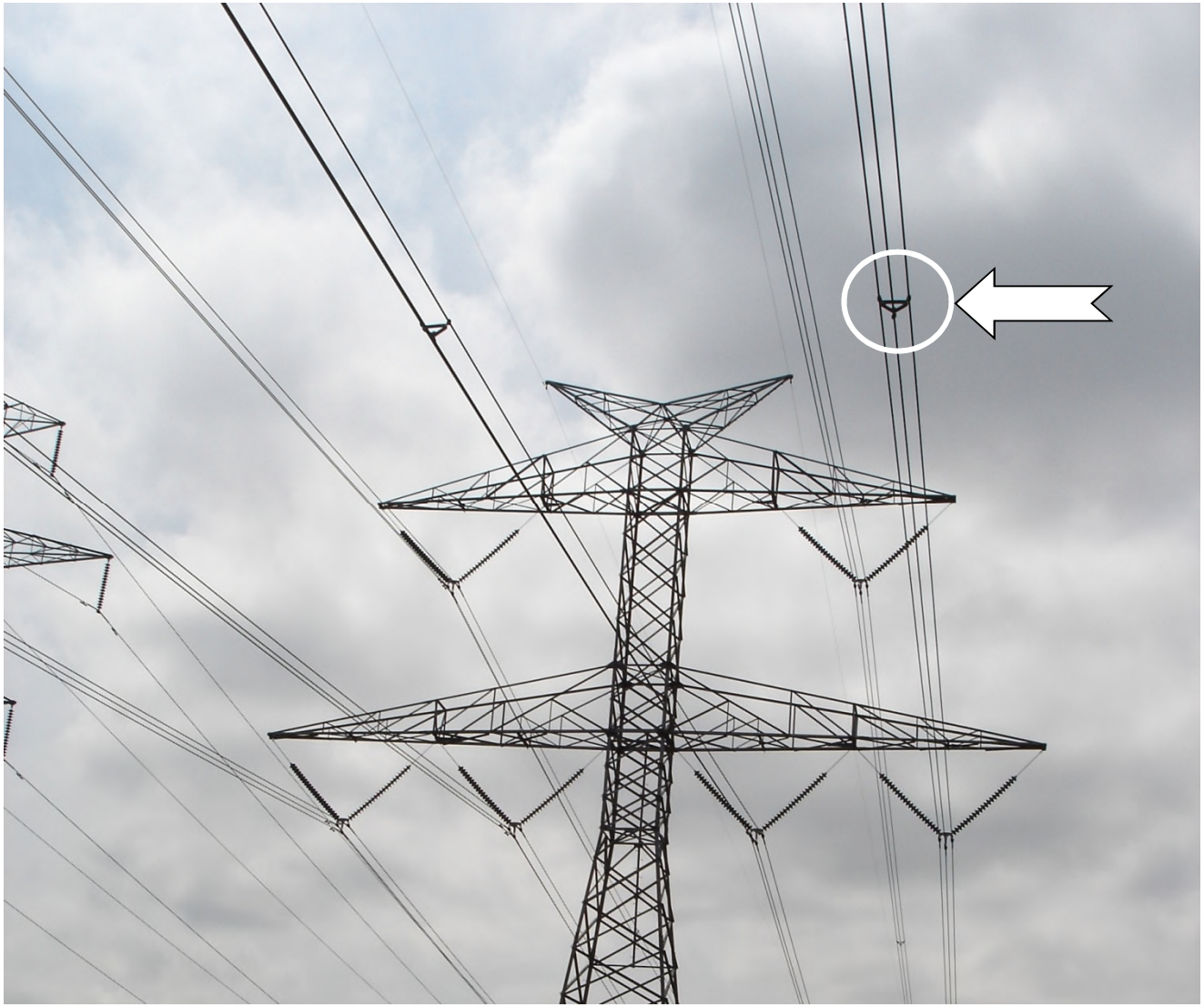
Why Using Bundled Conductors?

- Having a bundled conductor, increases the overall diameter, thus reducing the corona
- Bundled conductors are only used for high voltage transmission lines (normally 340 kV or higher)
- Spacers are used to equalize the voltage between the sub-conductors



Bundled Conductors

Bundled Conductors

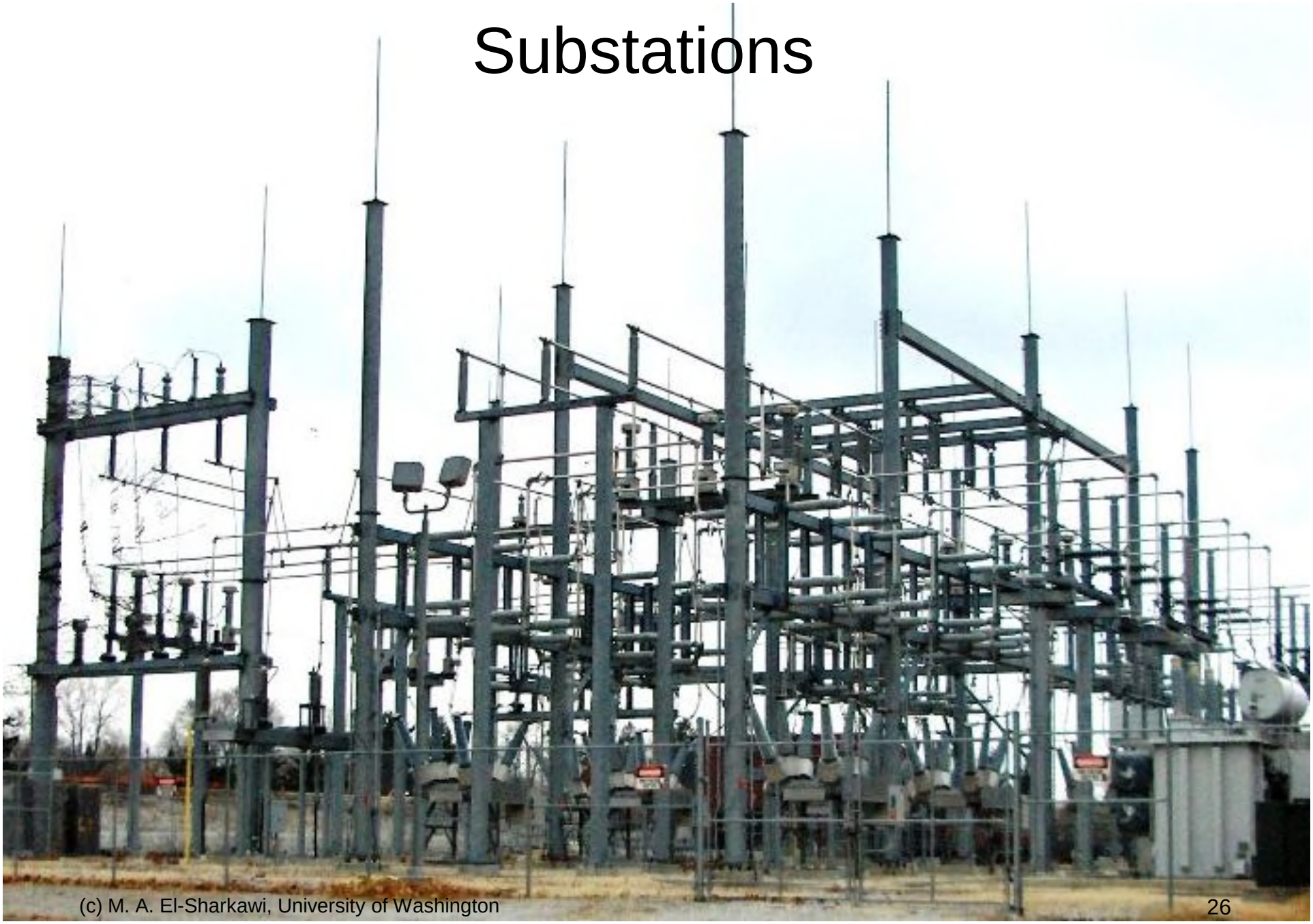


Static, Shield or Ground Wire

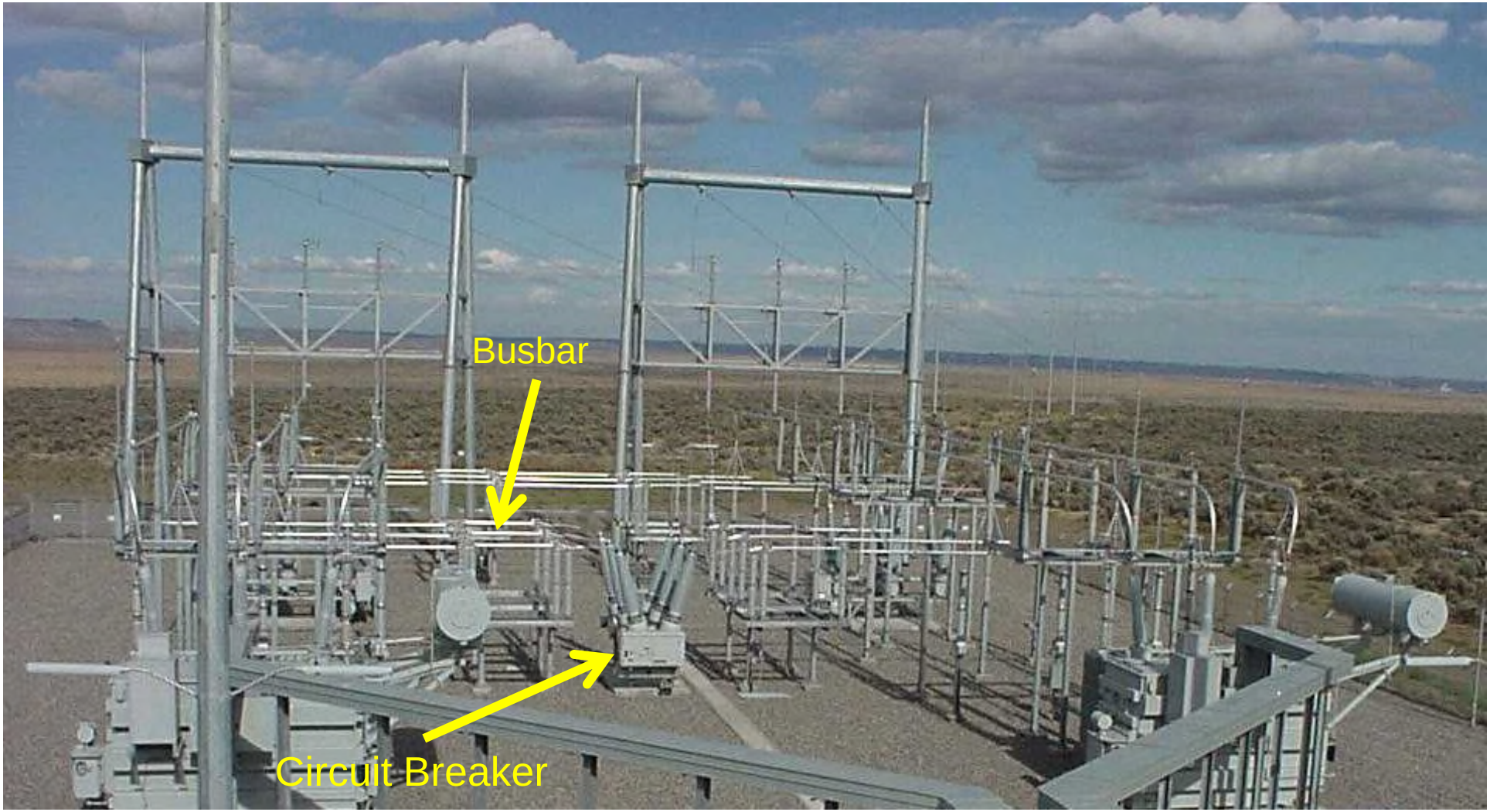
Function of Static Wire

- To protect (shield) the line from lightning strikes.
  - The static wire is the highest wire at ground potential
  - Lightning hits the highest point with lowest potential
- The static wire dissipates the lightning energy throughout all ground points along the transmission line.

Substations



Substation



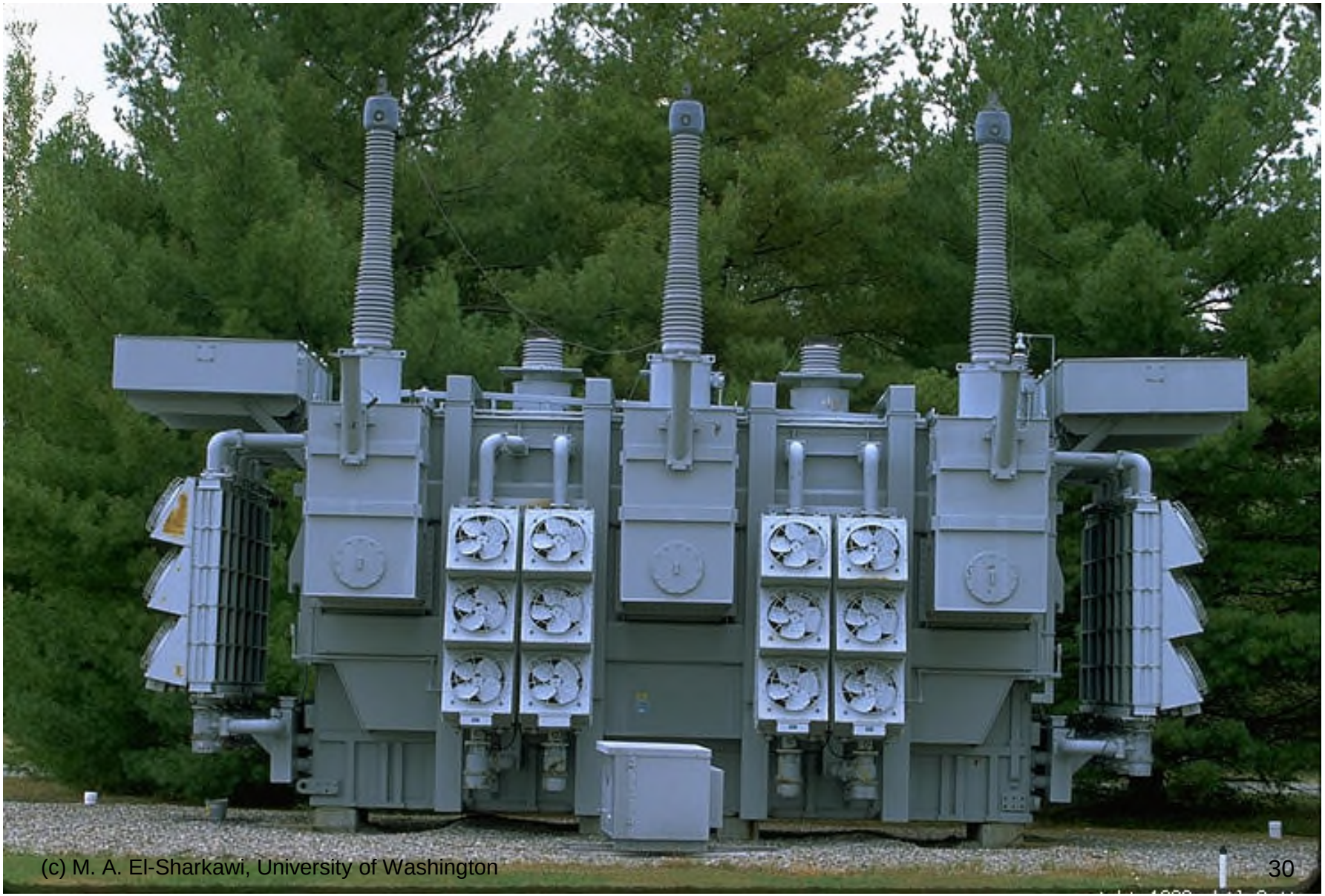
Main Components of Substation

- Transformers
- Switching equipment
  - Fuses
  - Circuit breakers and Recloser
  - Switches

Main Components of Substation

- Protection equipment
  - Surge protection
  - Grounding system
- Measurement Equipment
  - Current Transformers CT
  - Potential Transformers PT
- Control Equipment.
  - Power factor correction capacitors
  - Voltage regulators

Transmission Transformer



DistributionTransformers

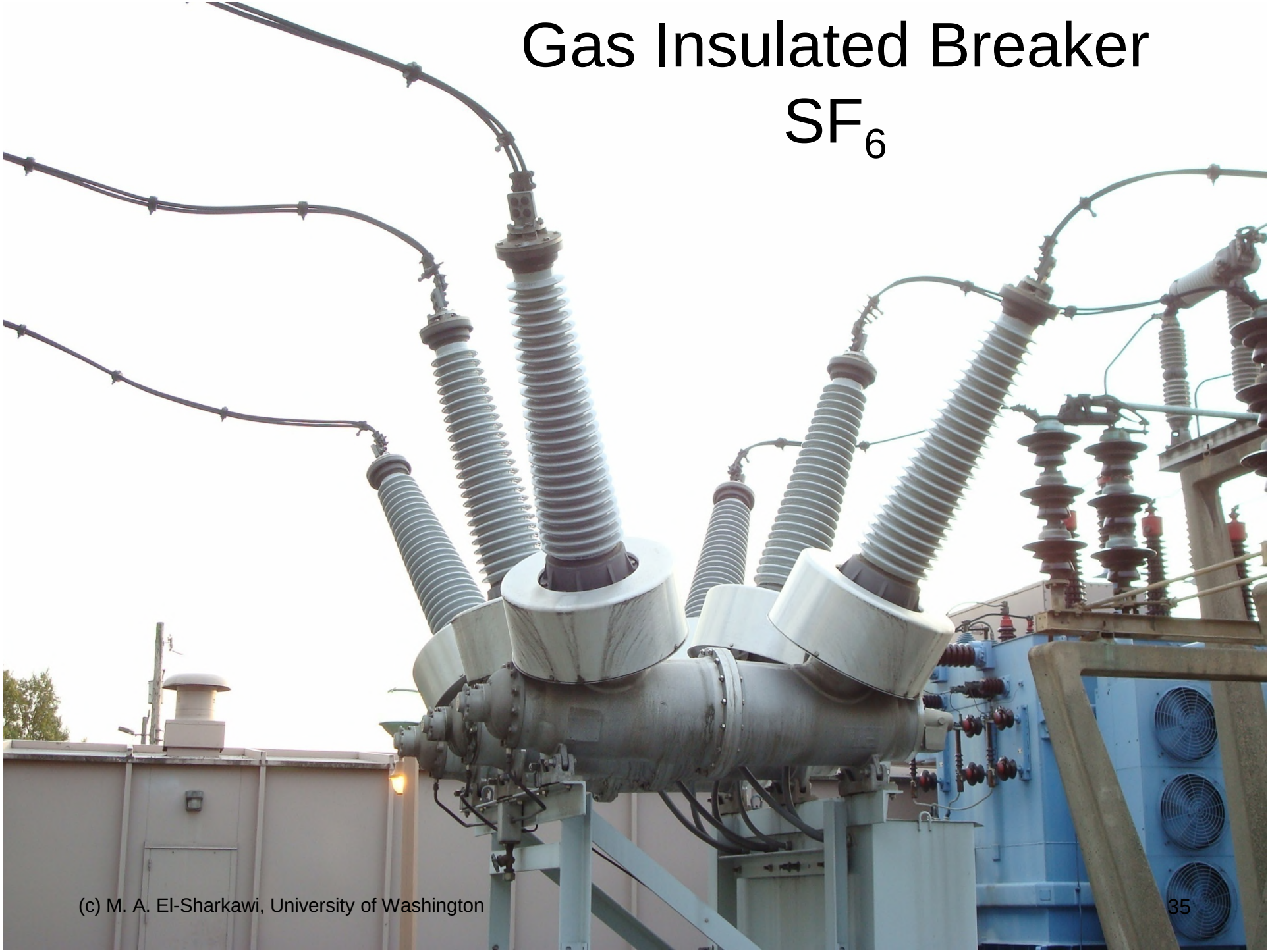
Service Transformer bank

Service Transformer

Circuit Breakers (CB)

- Automatic interrupting devices capable of breaking and closing a circuit even under fault conditions
- Can be controlled to interrupt currents above a specific value (tap setting) when it last for longer than a specific time (time dial setting)
- It is highly accurate device and very fast acting (within a cycle for modern CB)

Gas Insulated Breaker SF_6



Reclosers

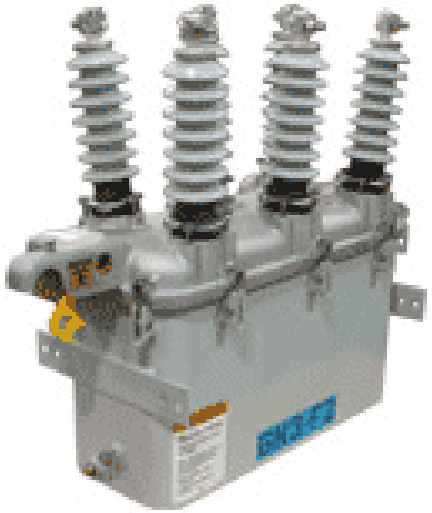
- Circuit breaker with automatic closing capability
  - interrupts fault currents
  - Automatically restore service after momentary outage.
- If a fault is permanent, the recloser locks open after a preset number of operations (usually three or four)
- Reclosers are less accurate than CBs and operates at lower currents.
  - Less expensive

reclosers

Single-phase recloser

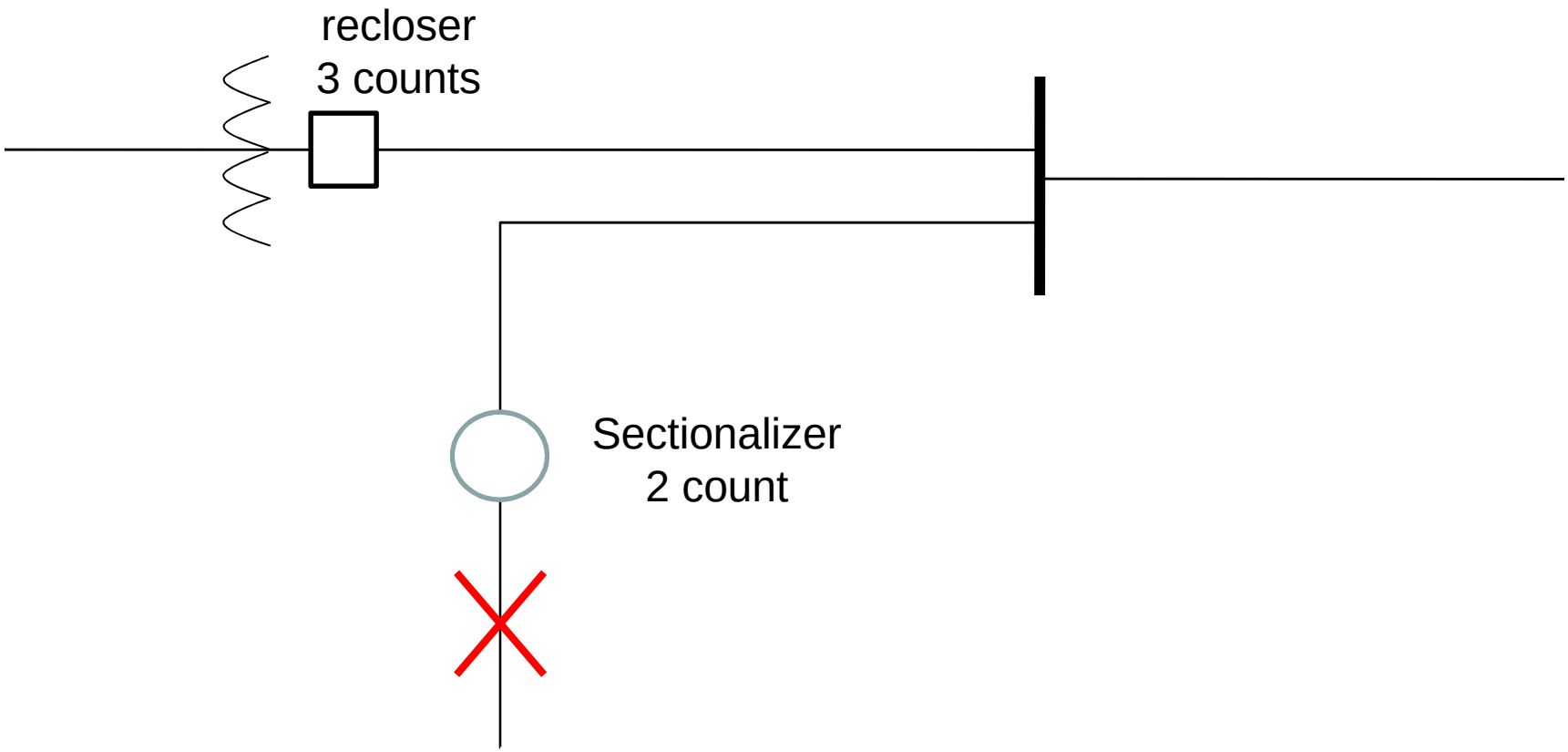
three-phase recloser

Sectionalizers

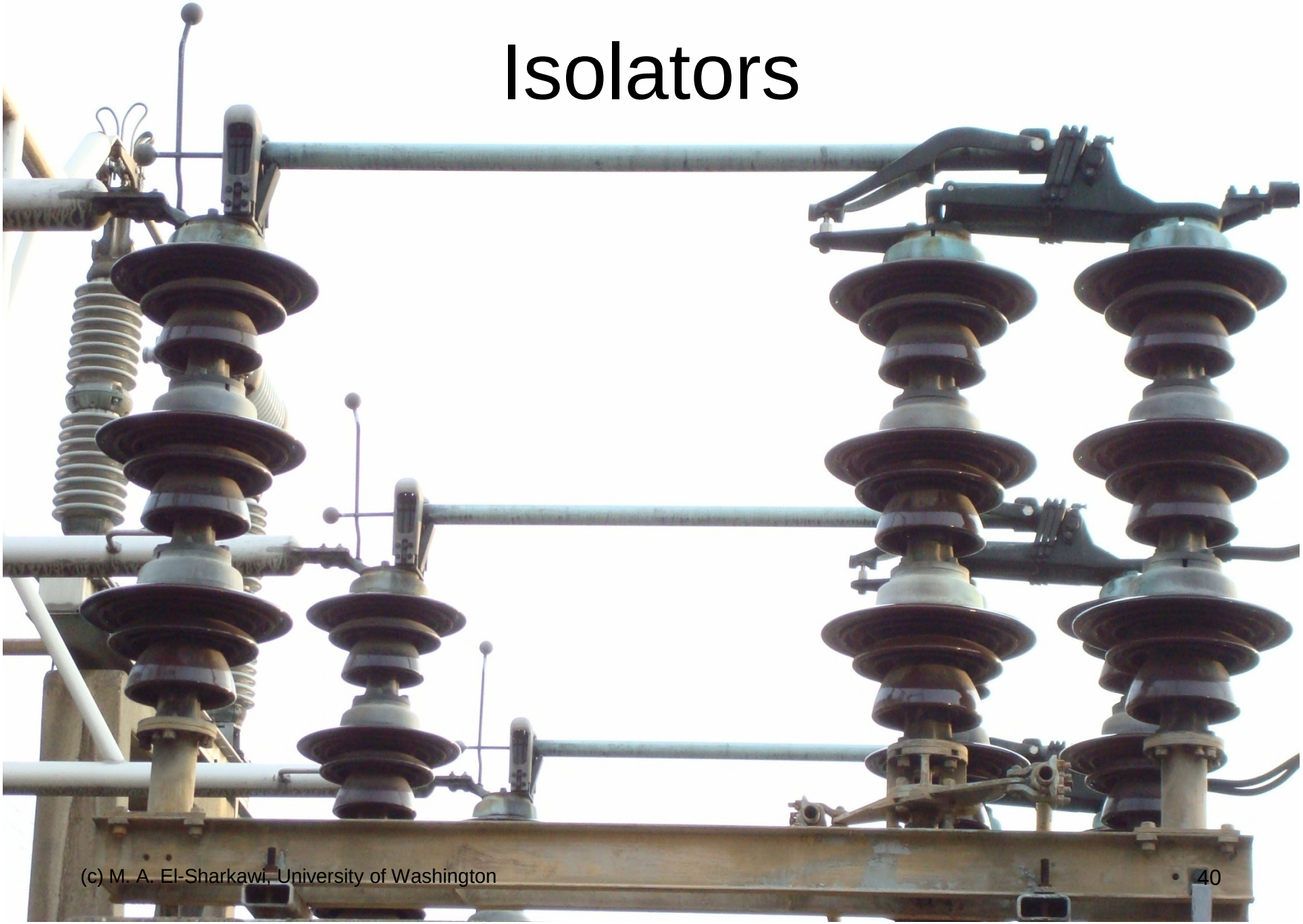


- Often used to isolate sections of the network
- Do not interrupt fault currents
- Work in conjunction with reclosers
- Before the recloser is locked in the open position, the sectionalizer is activated

Circuit Breaker and Sectionalizer

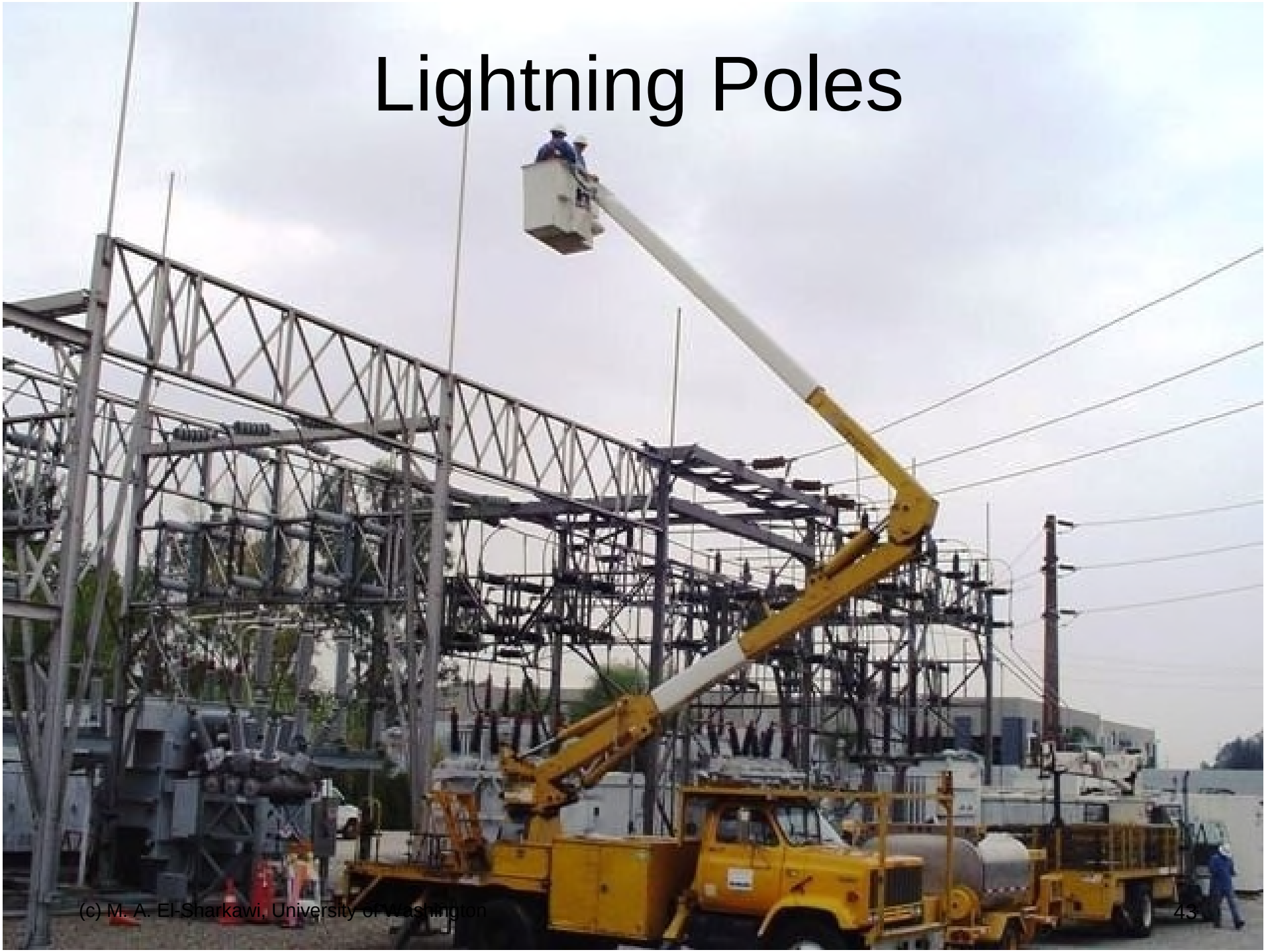


Isolators

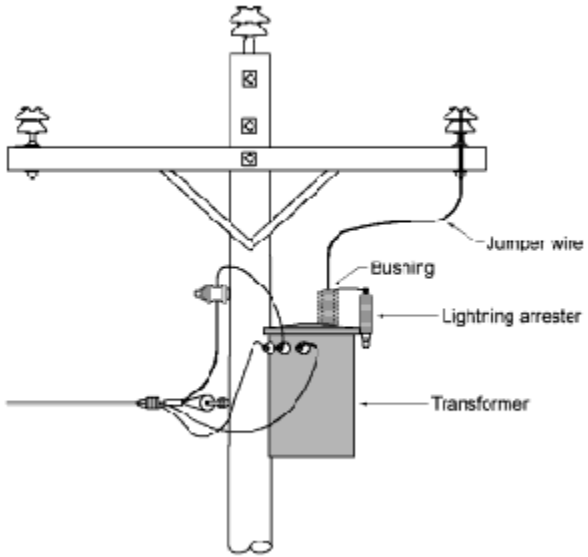


A 500 kV disconnect switch, one phase opens hot!

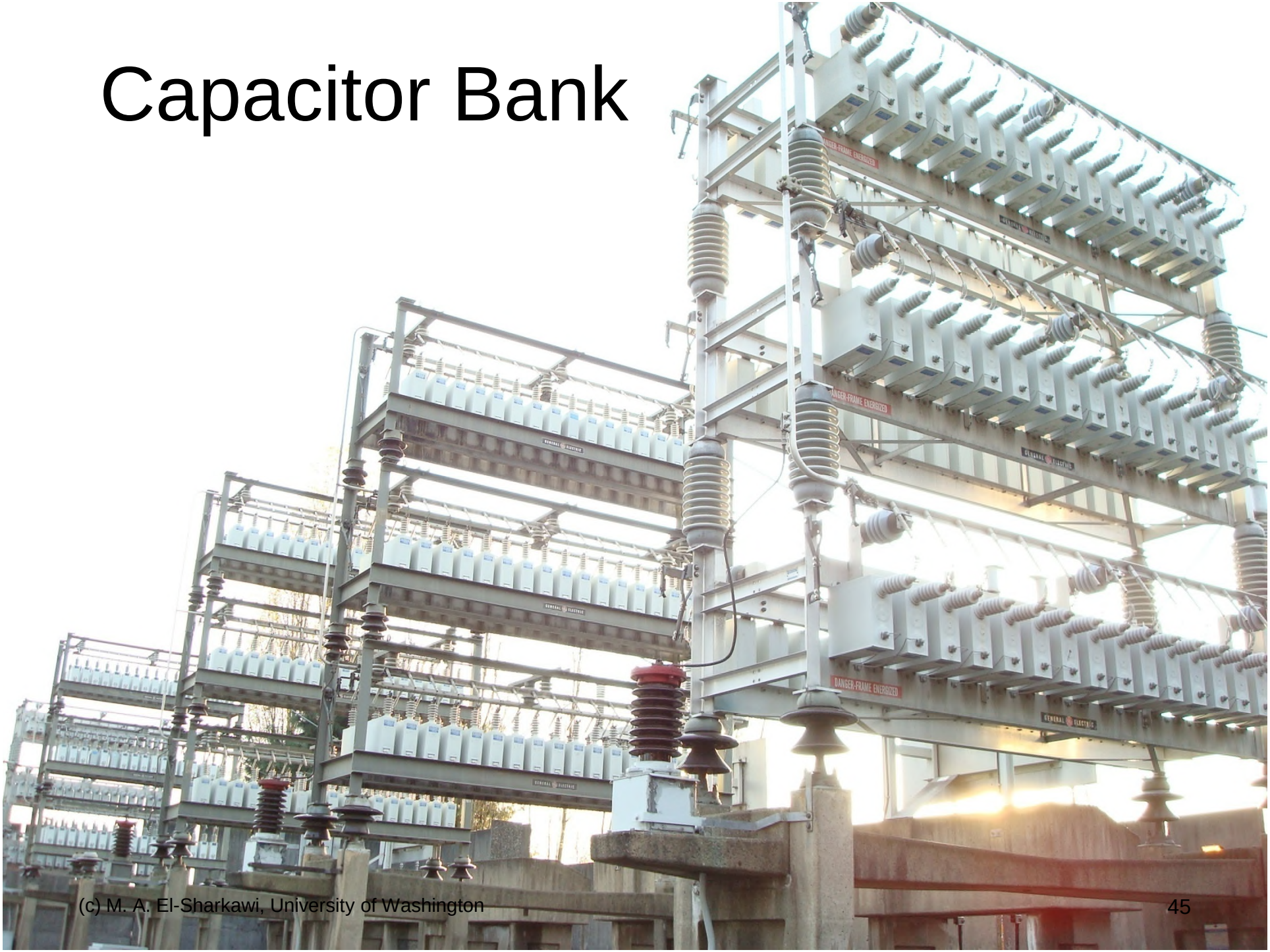
Lightning Poles



Lightning Arresters



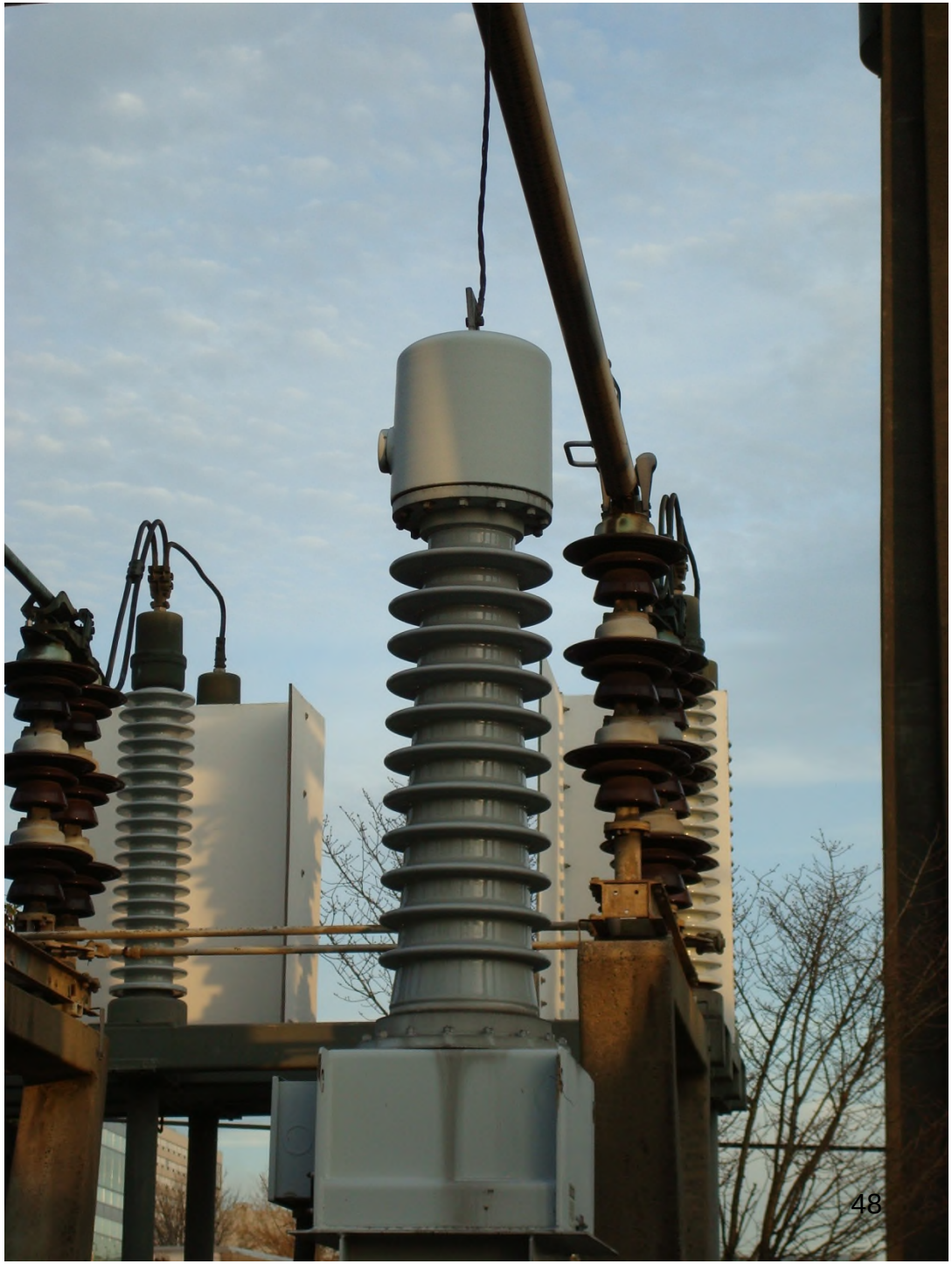
Capacitor Bank



Pole Mount Capacitors

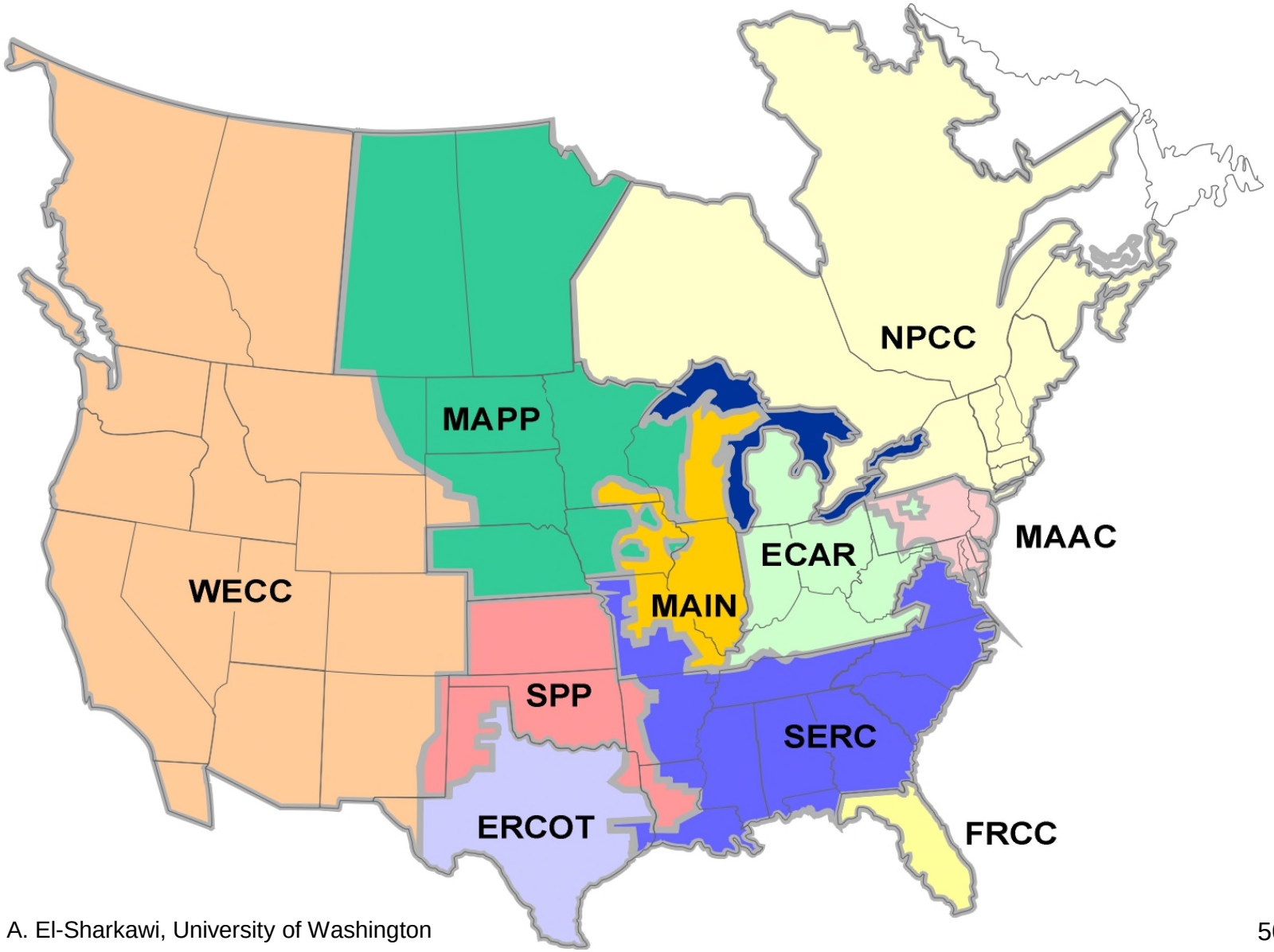
Busbars

PT
Cap Divider

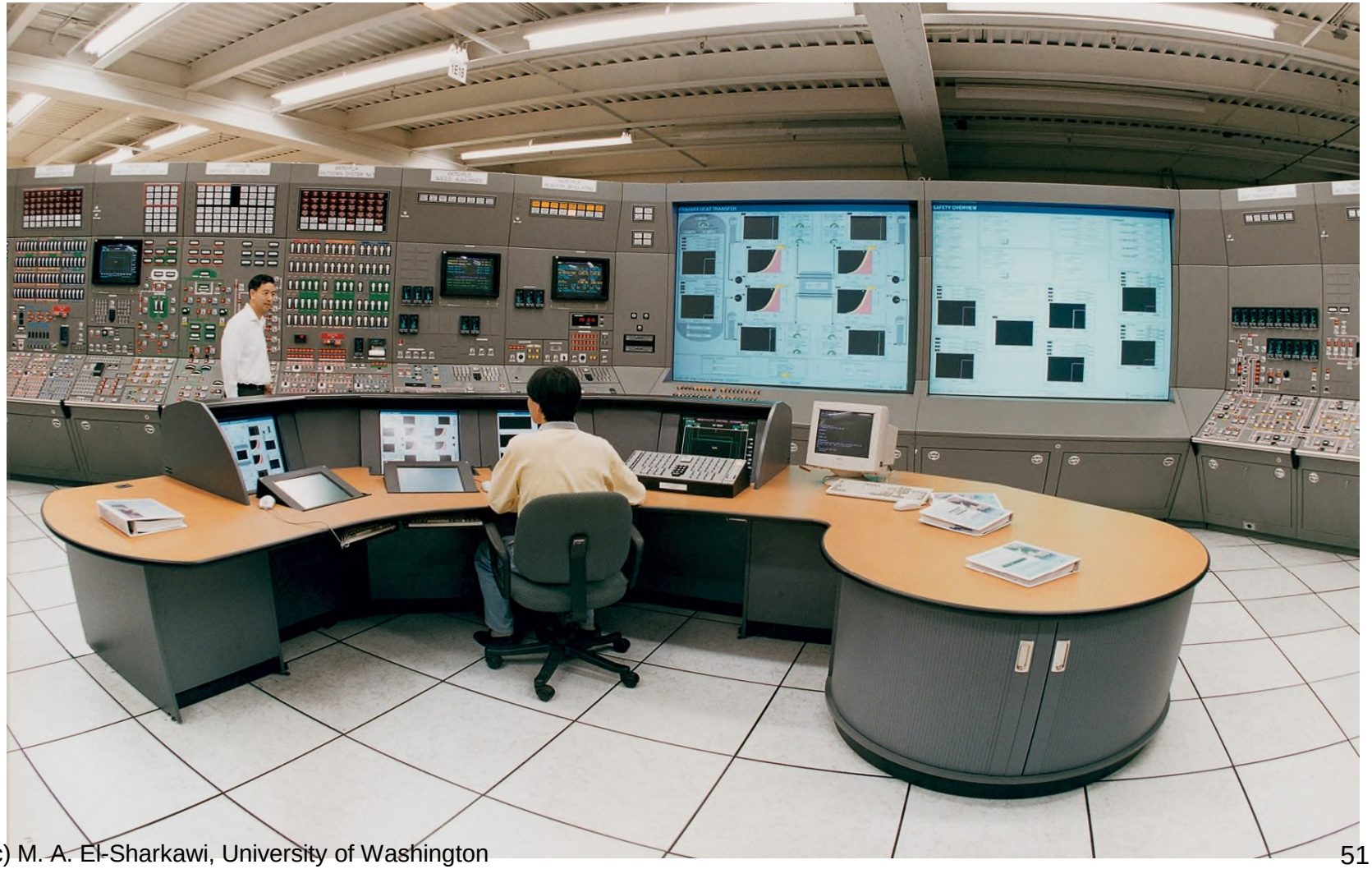


Auxiliary Power

North American Power Pools

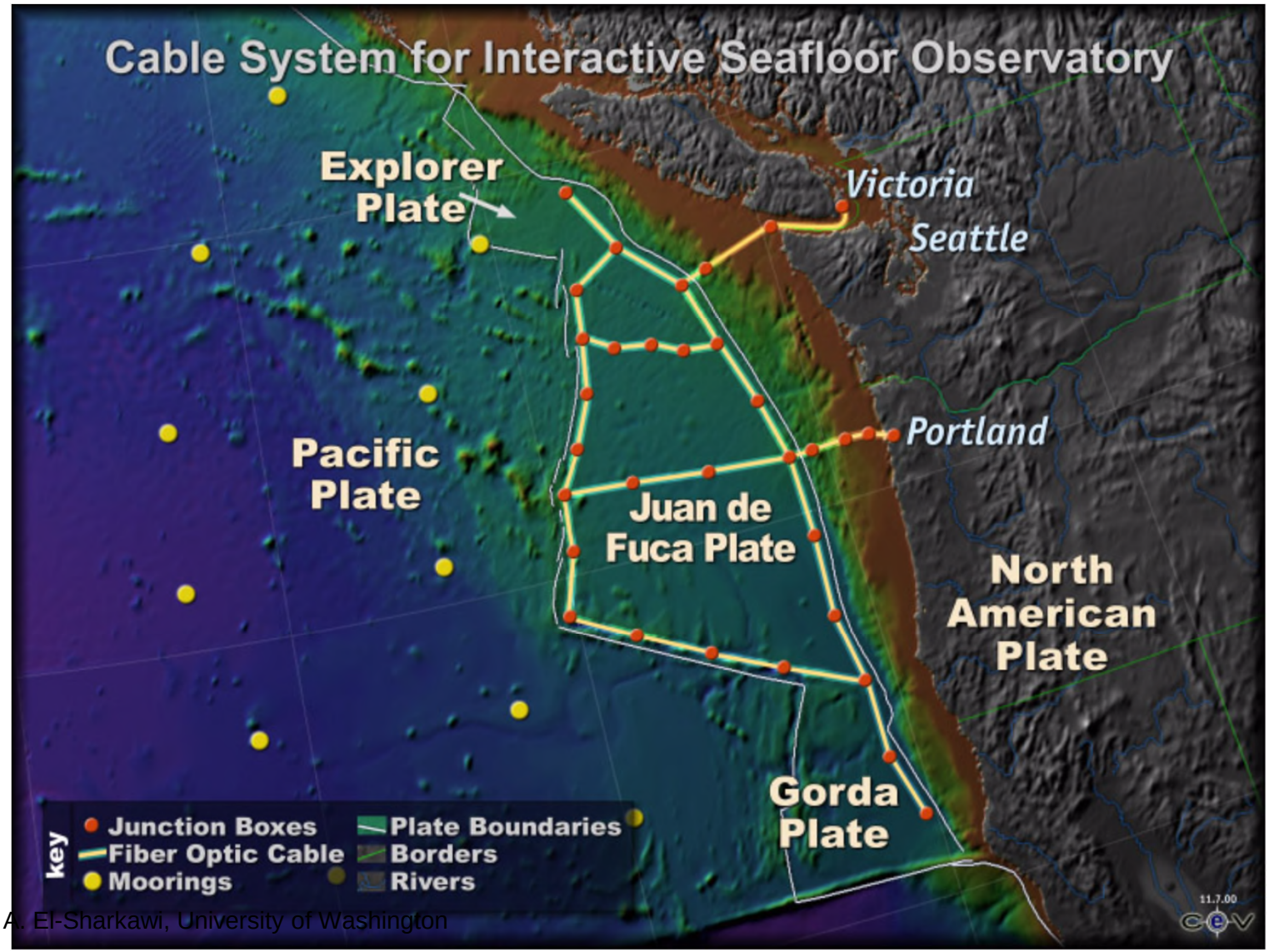


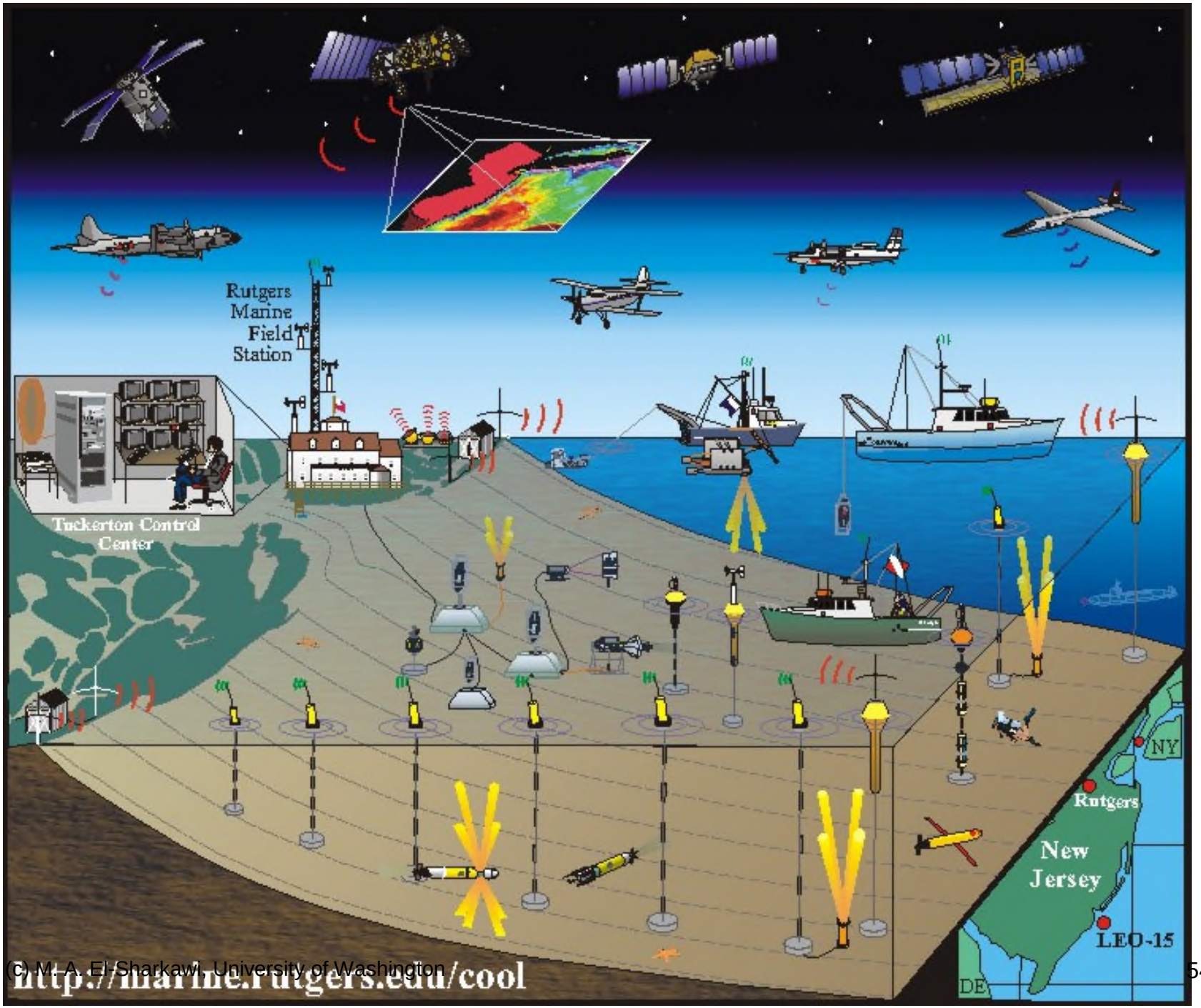
Nuclear Plant Control Center



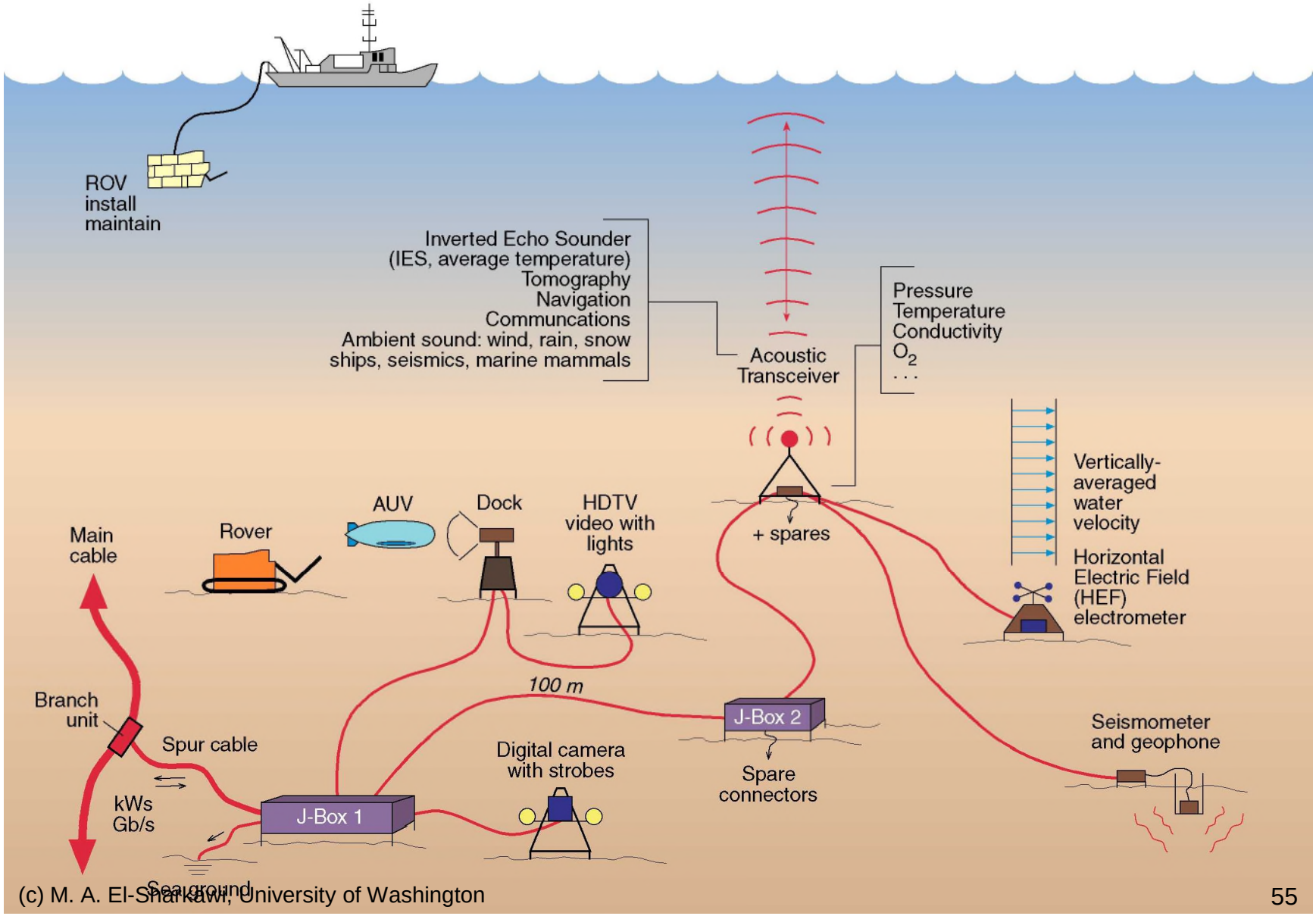
Grid Control Center

Special Power Systems




Rutgers
Marine
Field
Station
Tuckerton Control
Center
NY
Rutgers
New
Jersey
LEO-15
DE
http://marine.rutgers.edu/cool

NEPTUNE Basic Sensor Network




ATLANTIS II
WOODS HOLE
ALVIN

Space Power System

Smart Grid


Value added services
Forecast information
Off-shore wind
Small hydro power
Solar power plant
Hydro power station
Biomass
Low emission power plant
Local control and communication center
HVDC link
Transformer
Microgrid
Wave energy
Residential CHP
Solar
Photovoltaic
Underground info and power transmission
H_2 production and filling station
H_2
Demand side management
CHP
Micro storage of electricity
Thermal storage
SMES
Fuel cells
Compressed hydrogen storage