EEN-206: Power Transmission and Distribution

Lecture -05

Chapter 2: Overhead Transmission Lines

- **Introduction to Overhead Lines**
- **Mechanical Design**

Syllabus (Autumn 2020-21)

1. Subject Code: **EEN-206** Course Title: **Power Transmission & Distribution**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory:3** **Practical:0**

4. Relative Weight: **CWS: 50** **PRS:00** **MTE:0** **ETE:50** **PRE:00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **DCC**

1. Introduction (Power Transmission and Distribution Systems)
2. Overhead Transmission Lines
3. Underground Cables
4. Line Parameters and Performance of Transmission Lines
5. HVDC Transmission Systems
6. Tariff
7. Surge Performance and Travelling Waves

Reference Books

- B. M. Weedy, B. J. Cory, N. Jenkins, Janaka B. Ekanayake, and Goran Strbac, "Electric Power Systems", 4th Ed., John Wiley and Sons, 2012
- Grainger J. J. and Stevenson W.D., Elements of Power System Analysis", Tata McGraw-Hill Publishing Company Limited, 2008.
- Gonen T., Electric Power Transmission System Engineering: Analysis and Design", John Wiley and Sons, 1990.
- Nagrath I. J. and Kothari D. P., "Power System Engineering", 3rd Ed., Tata McGraw-Hill Publishing Company Limited, 2008
- Roy S., "Electrical Power System- Concepts, Theory and Practices". Prentice Hall of India Private Limited, 2007
- C. L. Wadhwa, Electrical Power System, New Age Techno Press, New Delhi, 2010.
- S. N. Singh, Electric Power Generation, Transmission and Distribution, Second Edition, PHI, New Delhi, 2011.

Chapter 2: Overhead Transmission Lines

Mechanical and electrical design and operational aspects of overhead transmission lines

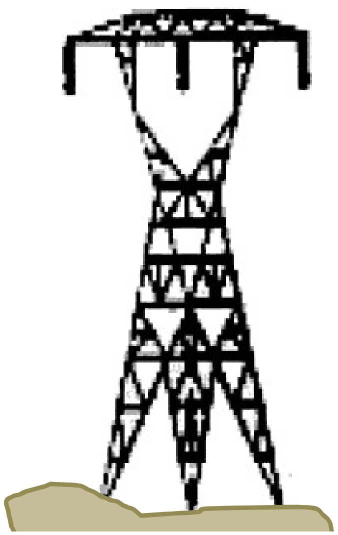
Main Components of Overhead Line

- **Support Structure (Towers)**: Cost, voltage level, conductor size, conductor spacing (cross-arm length), etc.
  - Galvanized steel (for high voltage)
  - Wood, concrete, steel poles (for low voltage)

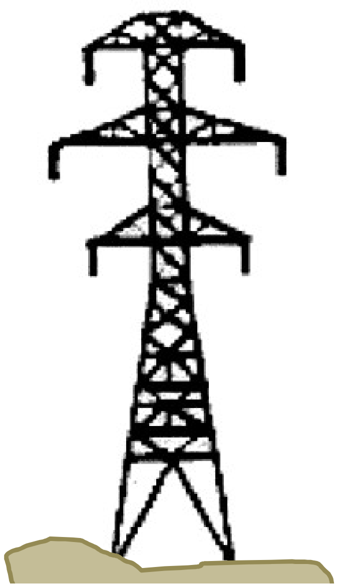
- **Insulators:** Voltage level
  - Porcelain
  - Glass
  - Polymeric insulation

- **Conductors:** Thermal limit, weight, conductivity, mechanical strength, regulation, etc.

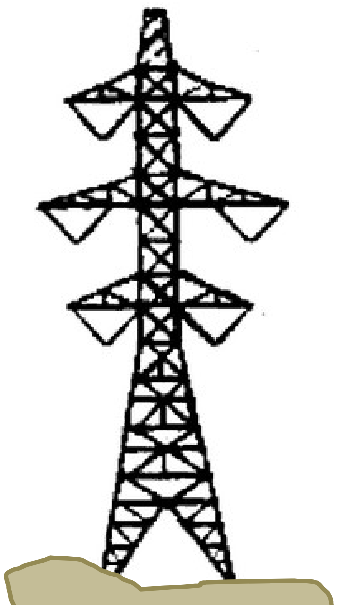
Tower Structures (High Voltage Transmission)



Single-Circuit



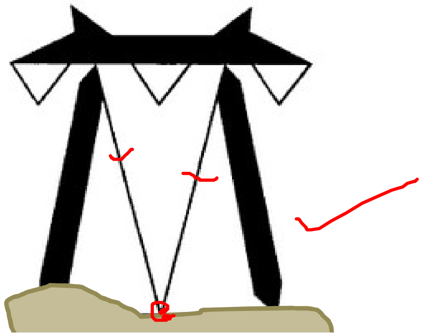
Double-Circuit

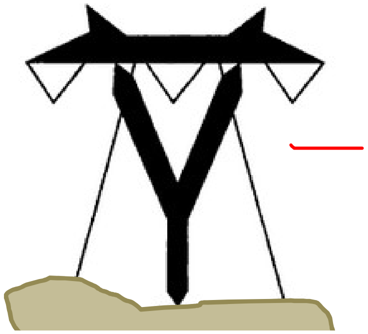


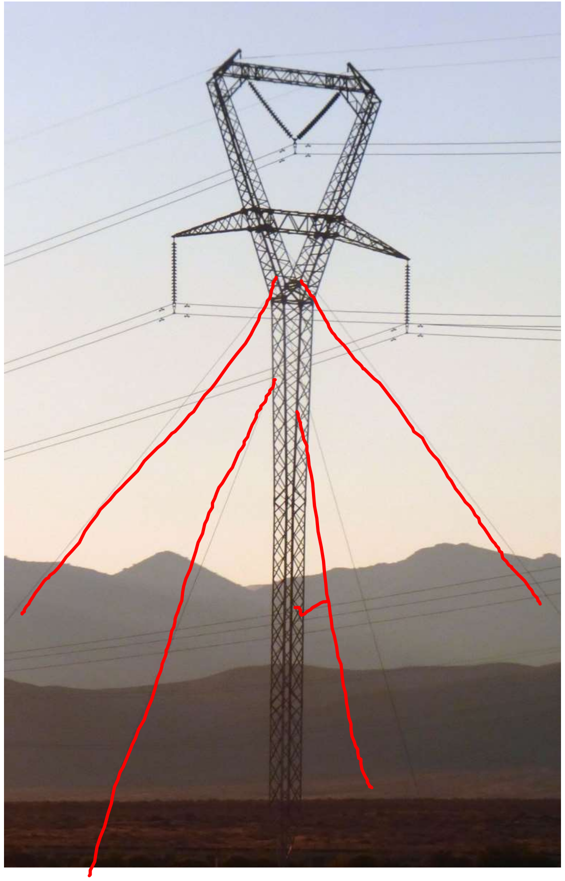
Double-Circuit
V String

Self-supporting towers

Tower Structures (Guyed Wire)

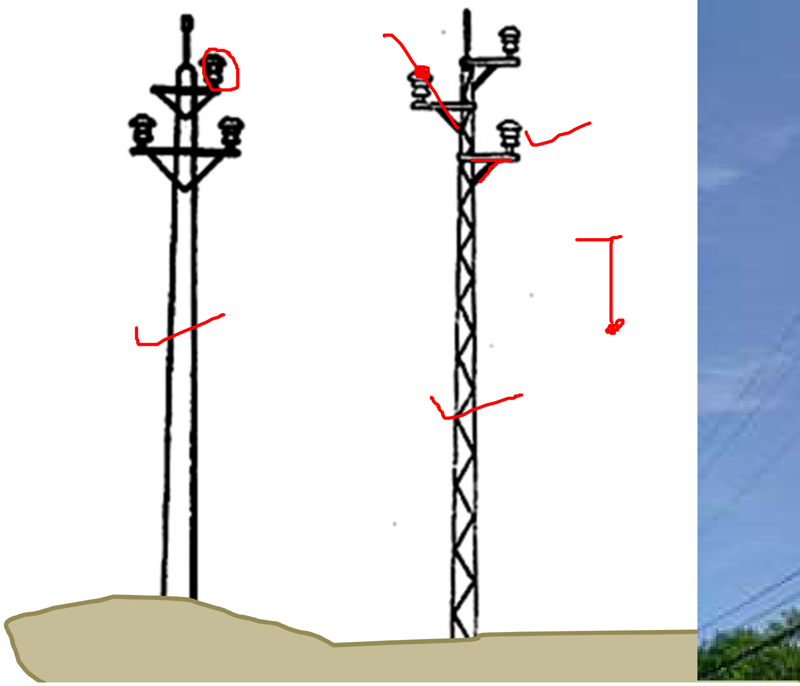






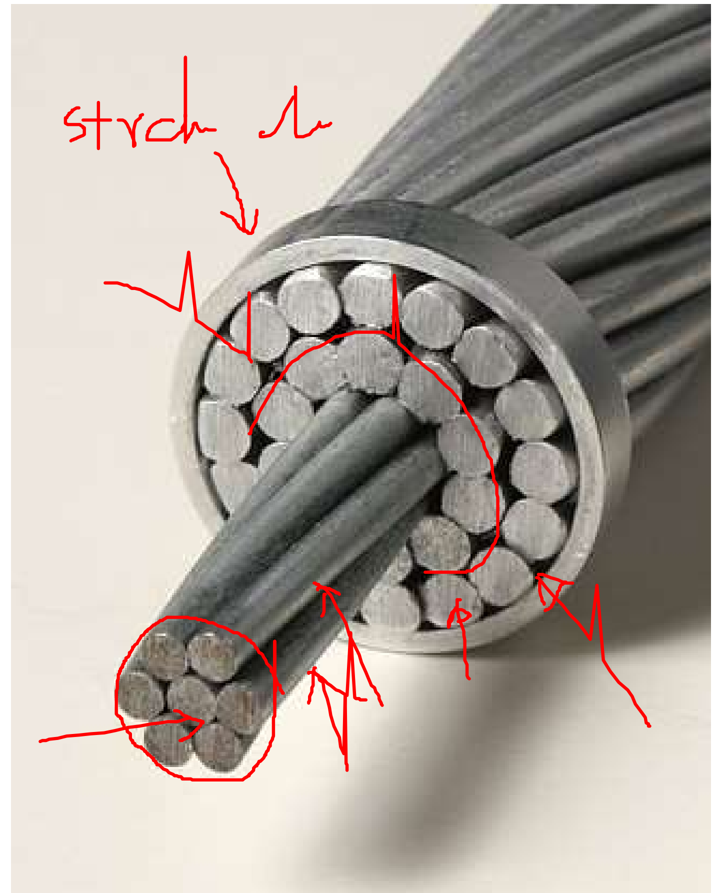
Guyed wire towers

Tower Structures (Low Voltage Distribution)

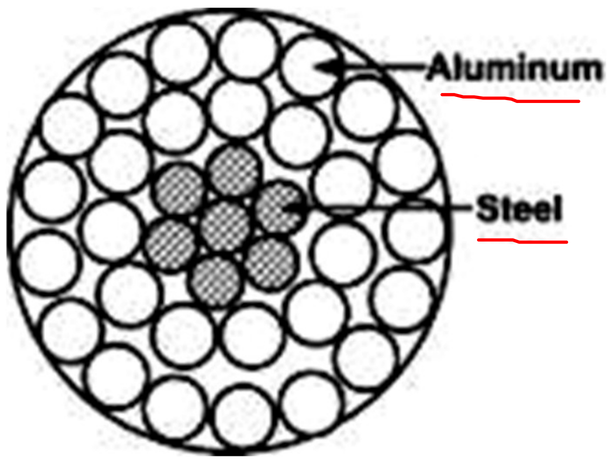


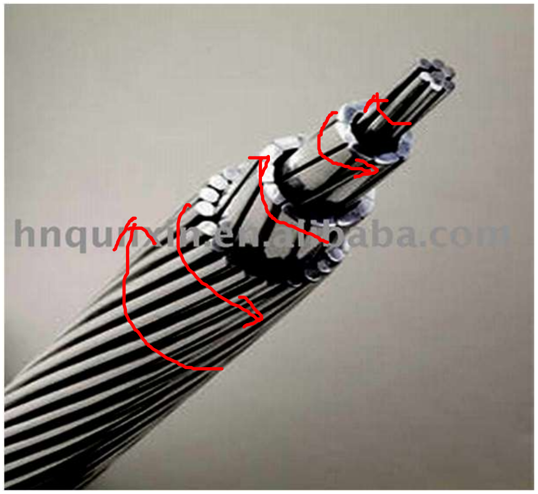
Types of Conductor

- Copper: Good conductor, durable, high scrap value, tensile strength, but cost is high.
- **Aluminum:**
  - **Cheaper,**
  - **lighter,**
  - **but less conductive (requires large cross section for same resistance)**
  - less tensile strength than copper
- Types of Aluminum conductors
  - AAC (All Aluminum Conductor)
  - AAAC (All Aluminum Alloy Conductor)
  - **ACSR (Aluminum Conductor Steel Reinforced)**
  - ACAR (Aluminum Conductor Alloy Reinforced)
  - Expanded ACSR



ACSR Conductor

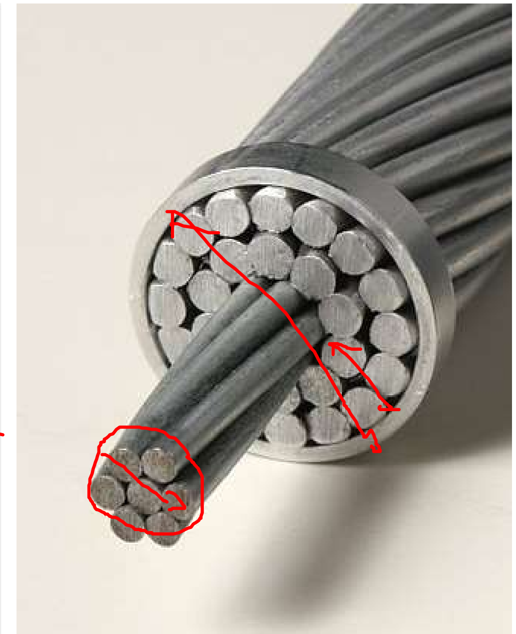




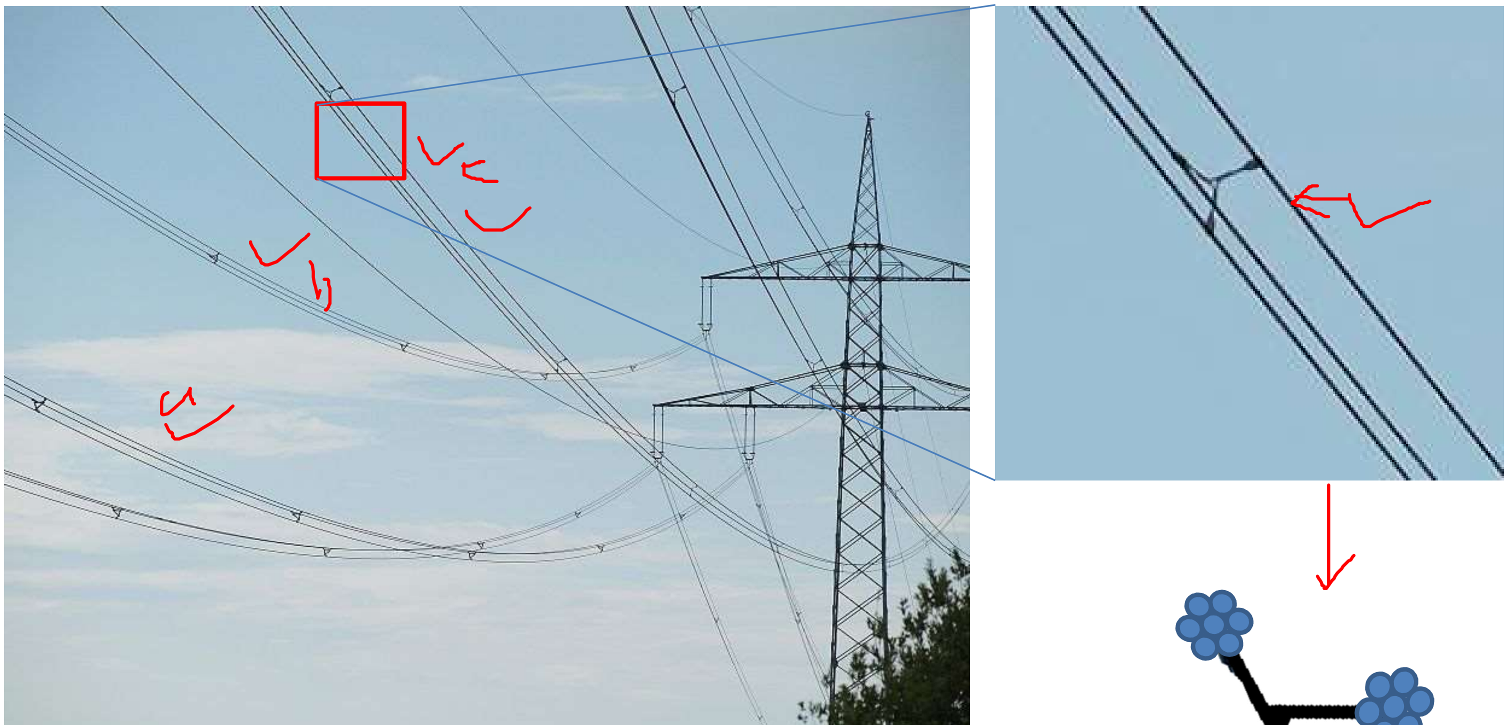
- Internal steel strands increase the tensile strength
- Outer aluminum strands carry the current
- Stranded conductor with twisted wires for strength and flexibility of mechanical handling.
- Twisting is done in opposite direction to avoid unwinding

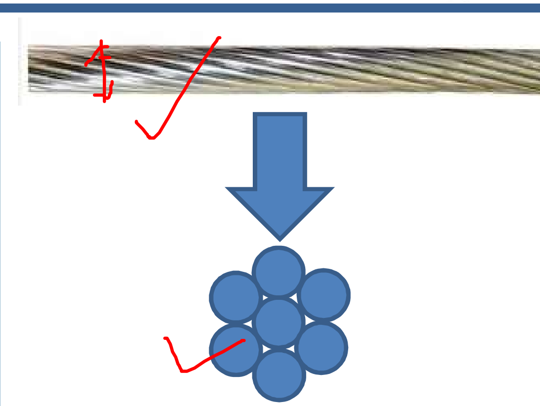
ACSR Conductor Data Sheets

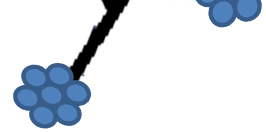
CODE NAME	NOMINAL ALUMINIUM AREA	EQUIVALENT COPPER AREA	CONDUCTOR CONSTRUCTION		APPROX. OVERALL DIAMETER	CALCULATED AREA	APPROX. WEIGHT	NOMINAL BREAKING LOAD	MAX. DC RESISTANCE AT 20°C	CURRENT RATING
			ALUMINIUM	STEEL						
	mm²	mm²	No./mm		mm	mm²	kg/km	N	Ω/km	Amp
GOPHER	25	16.1	6/2.36	1/2.36	7.08	30.62	106	9600	1.093	77
WEASEL	30	19.4	6/2.59	1/2.59	7.77	36.88	128	11400	0.9077	84
FERRET	40	25.8	6/3.00	1/3.00	9.00	49.48	172	15200	0.6766	98
RABBIT	50	32.3	6/3.35	1/3.35	10.05	61.70	214	18400	0.5426	112
HORSE	70	45.2	12/2.59	7/2.79	13.95	116.2	538	61200	0.3936	148
DOG	100	64.5	6/4.72	7/1.57	14.15	118.5	394	32700	0.2733	153
WOLF	150	96.8	30/2.59	7/2.59	18.13	194.9	726	69200	0.1828	162
DINGO	150	97.9	18/3.35	1/3.35	16.75	167.5	506	35700	0.1815	179
LYNX	175	113.0	30/2.79	7/2.79	19.53	226.2	842	79800	0.1576	178
CARACAL	175	113.7	18/3.61	1/3.61	18.05	194.5	587	41000	0.1563	205
PANTHER	200	129	30/3.00	7/3.00	21.00	261.5	974	92200	0.1363	191
BISON	-	226	54/3.00	7/3.00	27.00	431.3	1444	120900	0.07571	208
JAGUAR	200	130	18/3.86	1/3.86	19.30	222.3	671	46600	0.13670	197
ZEBRA	400	258	54/3.18	7/3.18	28.62	484.5	1621	131900	0.06740	202



Bundled Conductors

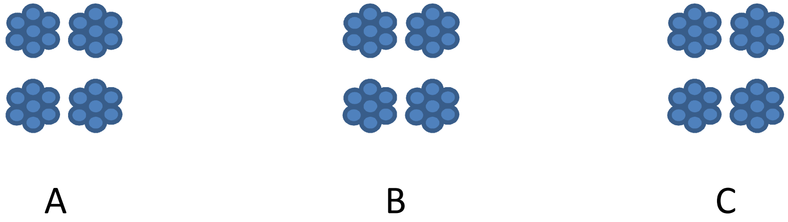


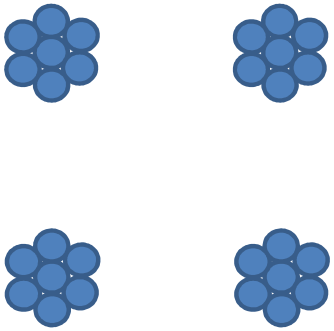


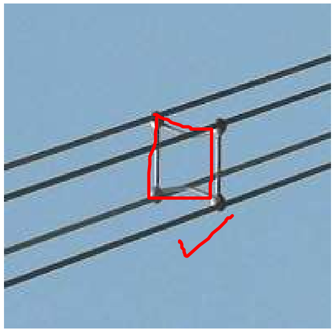


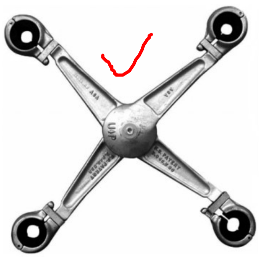
http://en.wikipedia.org/

Bundles Conductors

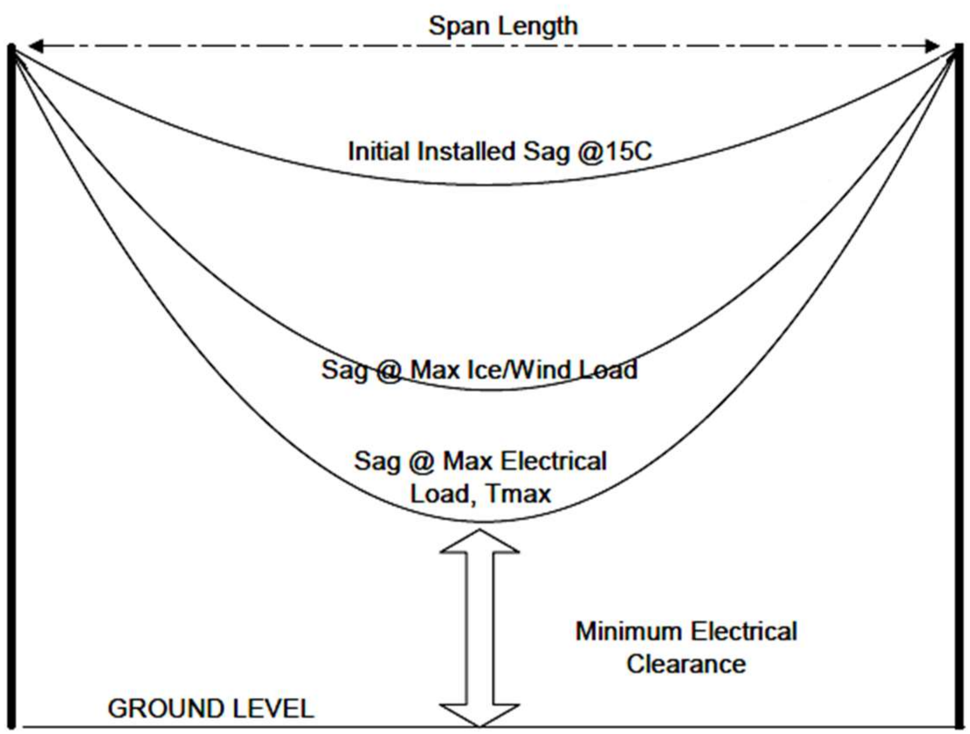








Sag and Tension:



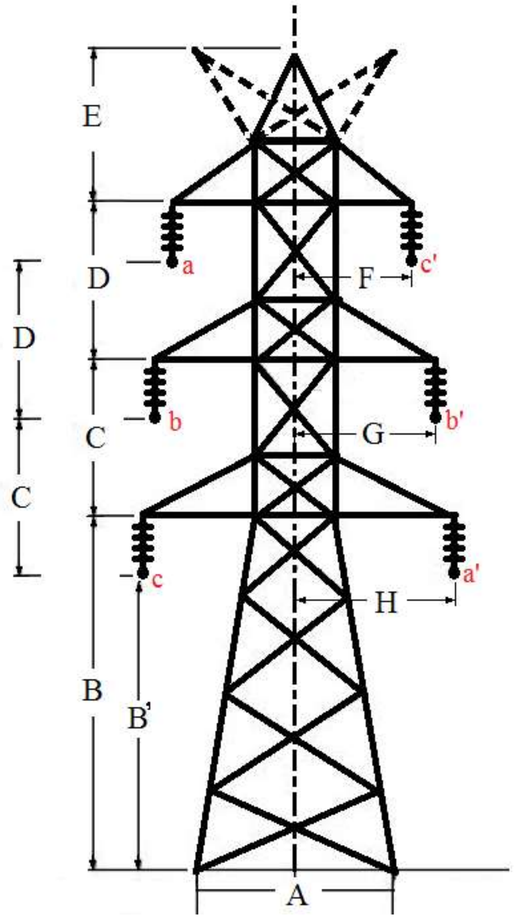
220 kV line	GC 7.0 m	SL 380	CC 5.1 m
400 kV line	GC 8.8 m	SL 400	CC 7.0 m

- **Sag (d)** is defined as vertical distance between the point where the line is joined to the tower to the lowest point on the line.
- Sag depends on the **tension (T)** with which conductors are pulled.
- **Span Length (SL)** is horizontal distance between two towers.
- Vertical distance between lowest point on line to the ground plane is called **ground clearance (GC)**.
- Values of sag and tension at **winter and summer condition** and at **various loading conditions** must be known.
- Tension in conductors contributes to the mechanical load on structures.
  - **Sag should be minimum to avoid extra pole height** and spacing between the conductors.
  - **Sag and tensions depends on initial tension** when are clamped in place.
  - **Stress in the conductor is function** of sag.

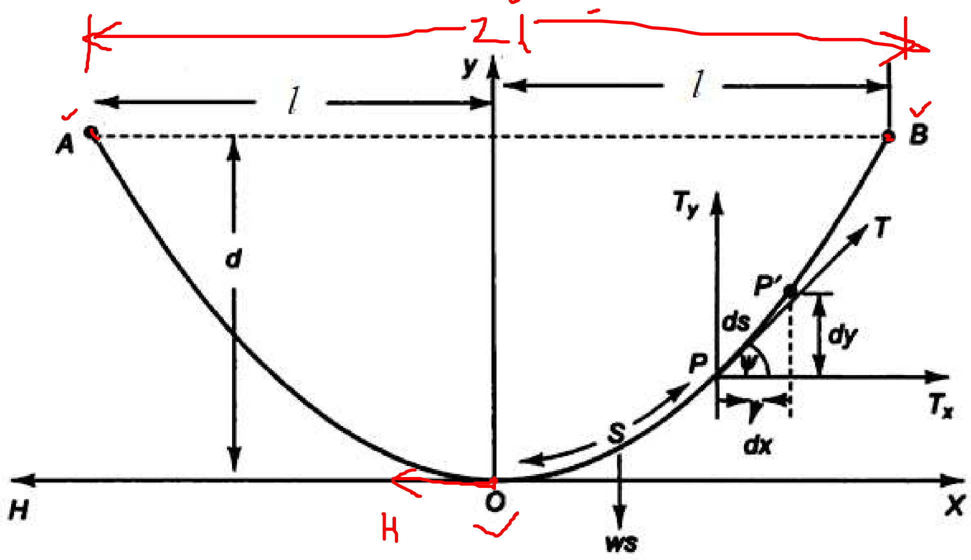
Transmission Line Mechanical Design

- **Mechanical Design Main Factors**
  - Conductor load per unit length
  - Tower spacing, span length
  - Temperature
  - Conductor tension

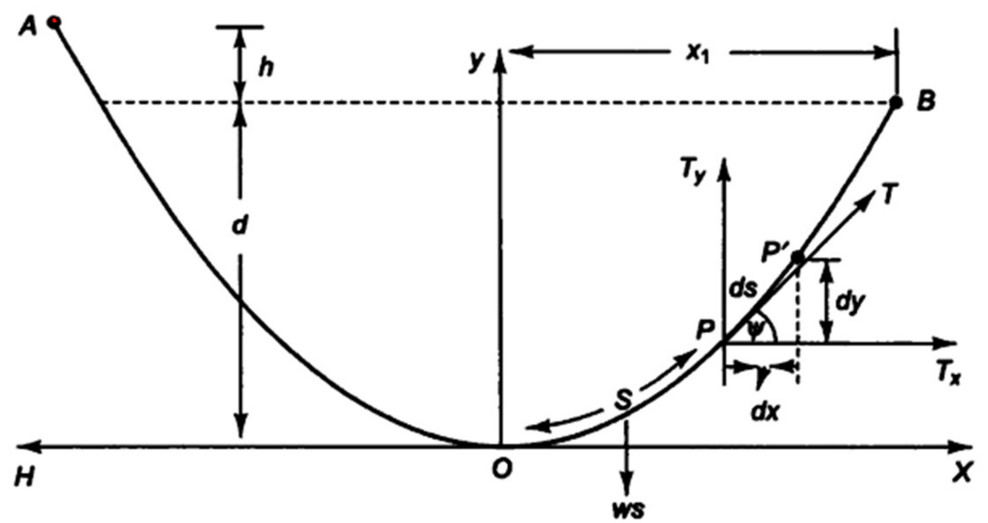
- **Mechanical loadings**
  - Weight of conductor itself
  - Weight of ice or snow clinging to wire
  - Wind blowing against wire



Calculation of Sag and Tension



Towers at same height



Towers at different height

- w =weight per unit length
- H = tension at point O
- T = tension at point P
- $2l$ =Span length
- O is the lowest point on the wire

Calculation of Sag and Tension

$$H = T_x$$

$$T_y = ws$$

$$\tan\,\psi = dy/dx = T_y/T_x = ws/H$$

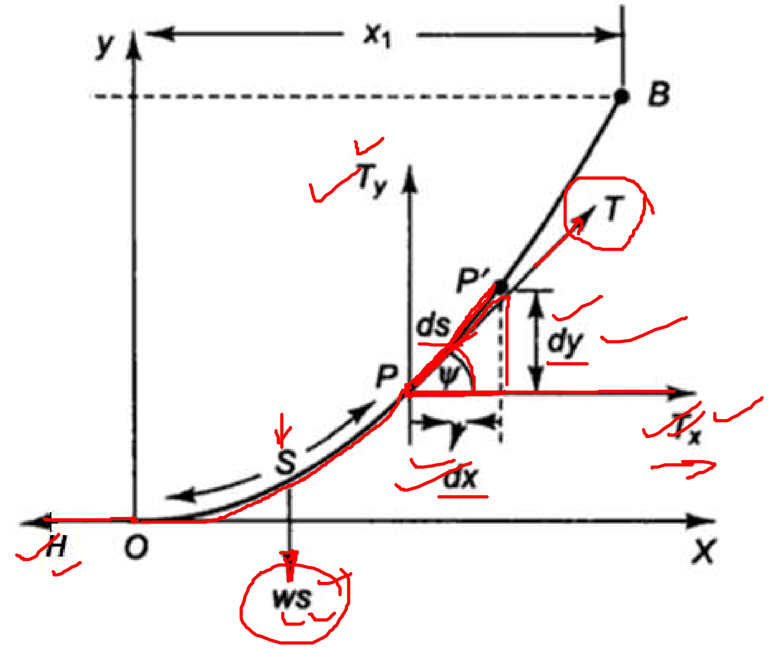
$$ds^2 = dx^2 + dy^2$$

$$\frac{ds^2}{dx^2} = 1 + \frac{dy^2}{dx^2}$$

$$\frac{ds}{dx} = \sqrt{1 + (dy/dx)^2}$$

$$\frac{ds}{dx} = \sqrt{1 + w^2 s^2 / H^2}$$

$$dx = \frac{ds}{\sqrt{1 + w^2 s^2 / H^2}}$$



Calculation of Sag and Tension

$$dx = \frac{ds}{\sqrt{1 + w^2 s^2 / H^2}}$$

Integrating

$$\int dx = \int \frac{ds}{\sqrt{1 + w^2 s^2 / H^2}}$$

Thus

$$x + c_1 = \frac{H}{w} \sinh^{-1}\left(\frac{ws}{H}\right)$$

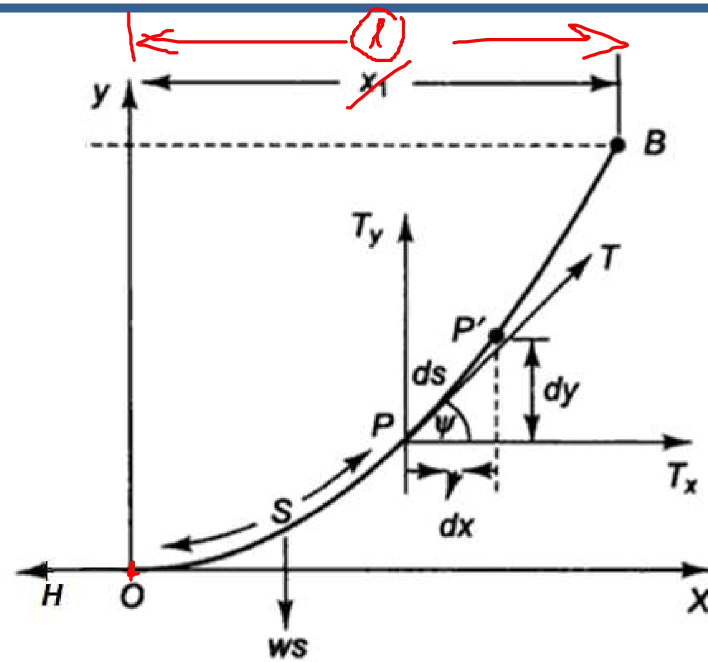
At x=0, s=0, therefore c_1=0

$$x = \frac{H}{w} \sinh^{-1}\left(\frac{ws}{H}\right)$$

$$s = \frac{H}{w} \sinh \frac{wx}{H}$$

Half

l



Thank You