Distributed-Parameter Representation

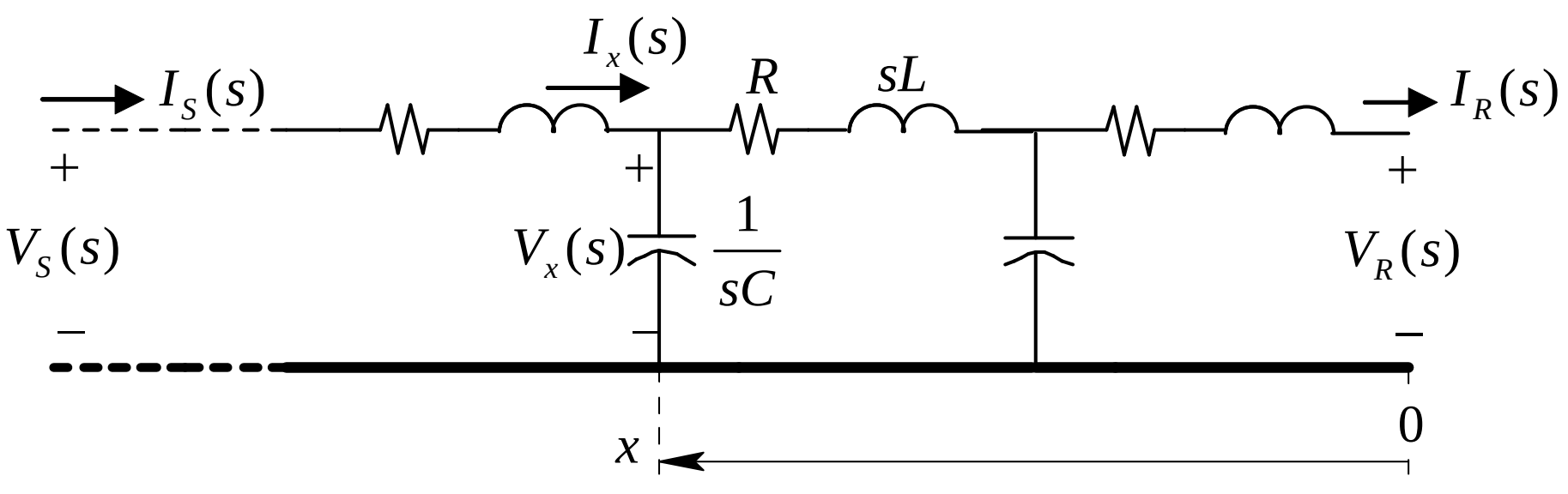


Fig. 4-9 Distributed per-phase transmission line (G not shown).

- Per-Phase

$$s = j\omega$$

$$V(s) = \bar{V} = V\angle\phi_v$$

Distributed-Parameter Representation

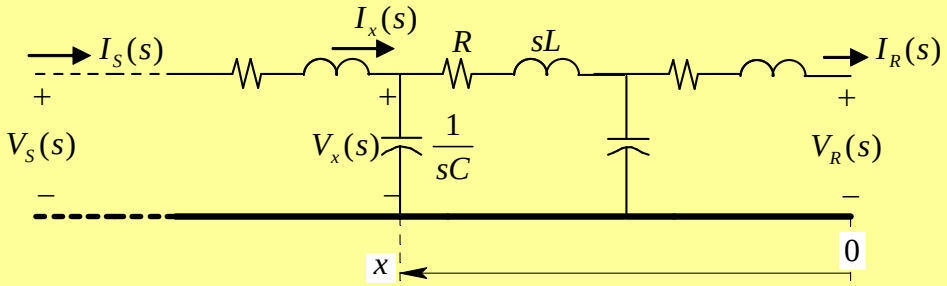


Fig. 4-9 Distributed per-phase transmission line (G not shown).

$$\gamma = \sqrt{(sL + R)(sC + G)} = \alpha + j\beta$$

$$Z_c = \sqrt{\frac{sL + R}{sC + G}}$$

$$V_x(s) = V_R(s)\cosh\gamma x + Z_c I_R(s)\sinh\gamma x$$

$$I_x(s) = \frac{V_R(s)}{Z_c}\sinh\gamma x + I_R(s)\cosh\gamma x$$

Surge Impedance Loading (SIL)

- Assume Lossless Line
  - R and G Neglected

$$\gamma = j\omega\sqrt{LC} = j\beta \qquad \beta = \omega\sqrt{LC} \qquad Z_c = \sqrt{\frac{L}{C}}$$

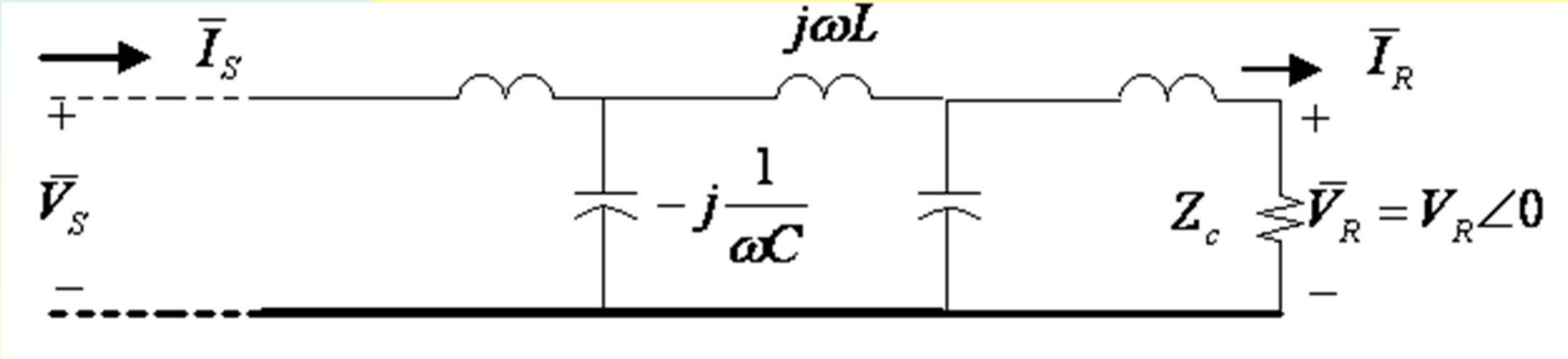


Fig. 4-10 Per-phase transmission line terminated with a resistance equal to Z_c.

$$\omega L I_x^2 = V_x^2 \omega C \qquad SIL = \frac{V_{LL}^2}{Z_c}$$

Voltage Profile With Surge Impedance Loading (SIL)

$$Z_c = \sqrt{\frac{L}{C}} \qquad SIL = \frac{V_{LL}^2}{Z_c}$$

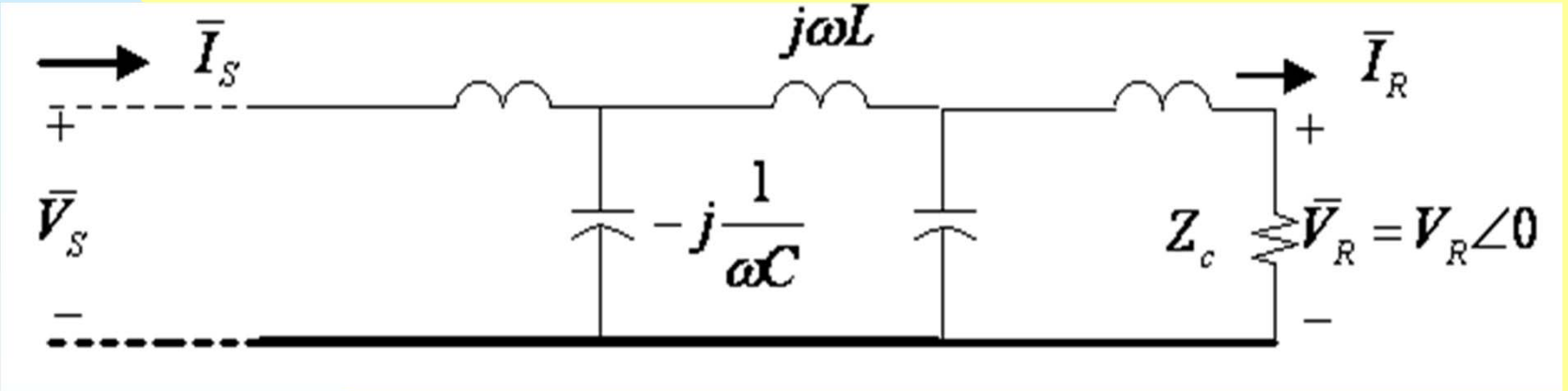
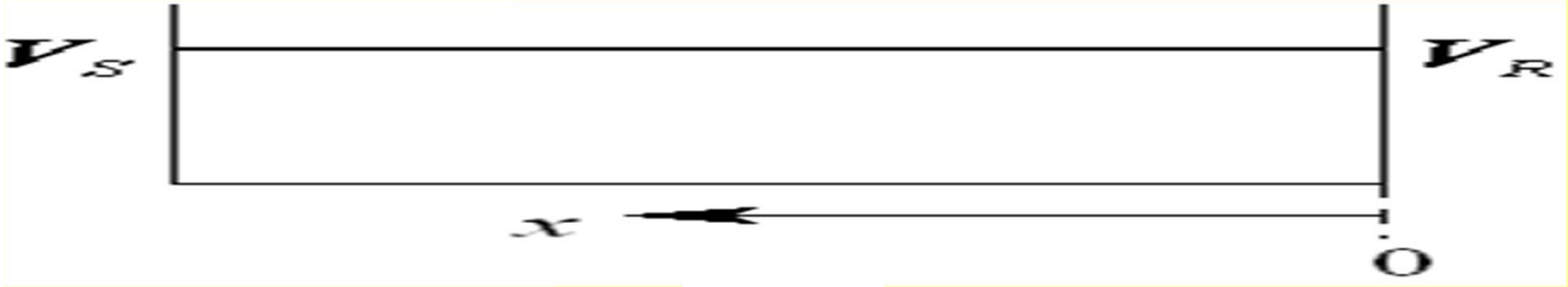


Fig. 4-10 Per-phase transmission line terminated with a resistance equal to Z_c.



Typical Surge Impedances and SIL for various Voltage Transmission Lines

Table 4-2

Surge Impedance and Three-Phase Surge Impedance Loading [2, 6]

Nominal Voltage	$Z_c(\Omega)$	$SIL\,(MW)$
230 kV	375	140 MW
345 kV	280	425 MW
500 kV	250	1000 MW
765 kV	255	2300 MW

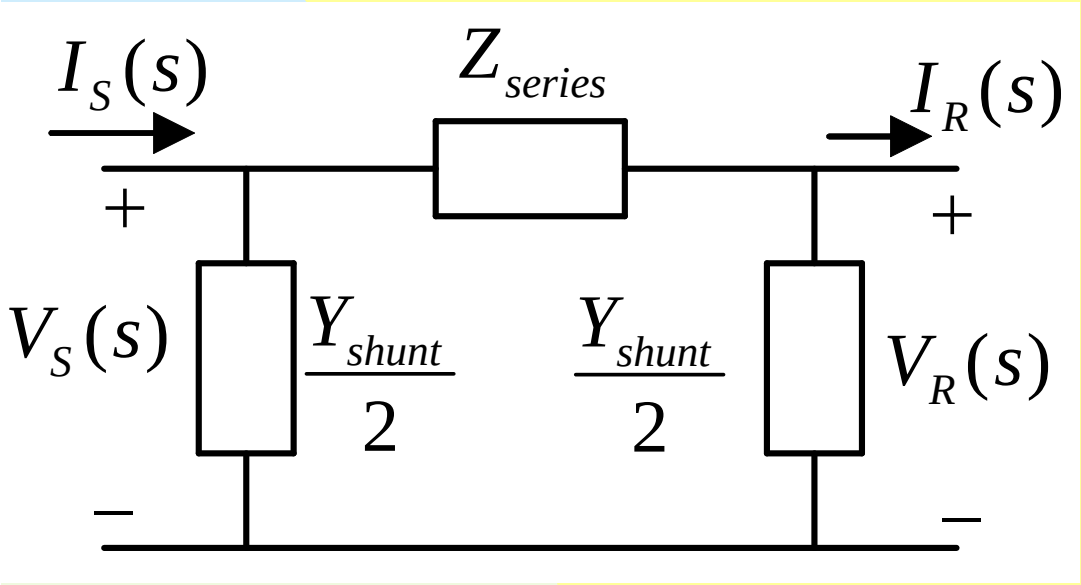
Loadability of Transmission Lines

Table 4-3

Loadability of Transmission Lines [6]

Line Length (km)	Limiting Factor	Multiple of SIL
0 - 80	Thermal	> 3
80 - 240	5% Voltage Drop	1.5 - 3
240 - 480	Stability	1.0 – 1.5

Lumped Model: Long-Line



$$\gamma = \sqrt{(sL+R)(sC+G)} = \alpha + j\beta$$

$$Z_c = \sqrt{\frac{sL+R}{sC+G}}$$

$$Z_{series} = Z_c \sinh \gamma \ell$$

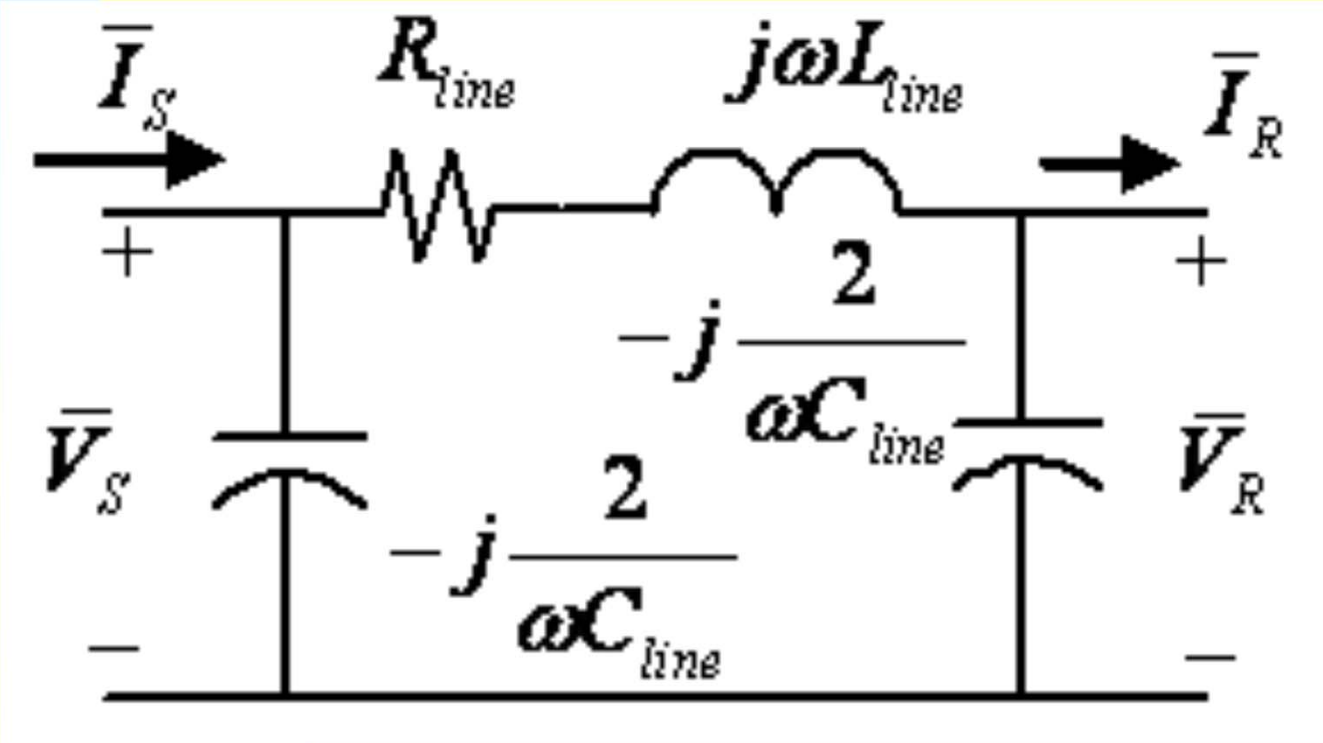
$$\frac{Y_{shunt}}{2} = \frac{\tanh\left(\frac{\gamma \ell}{2}\right)}{Z_c}$$

$$s = j\omega$$

$$V(s) = \bar{V} = V \angle \phi_v$$

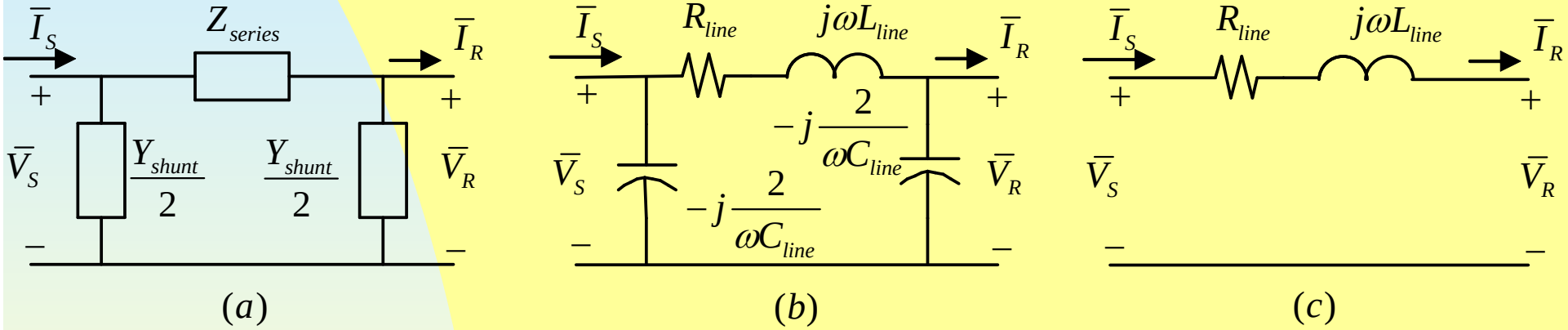
Lumped Model: Medium-Length Line

- Less than 200 miles



Lumped Model: Short-Length Line

- Less than 100 miles



Underground Cables

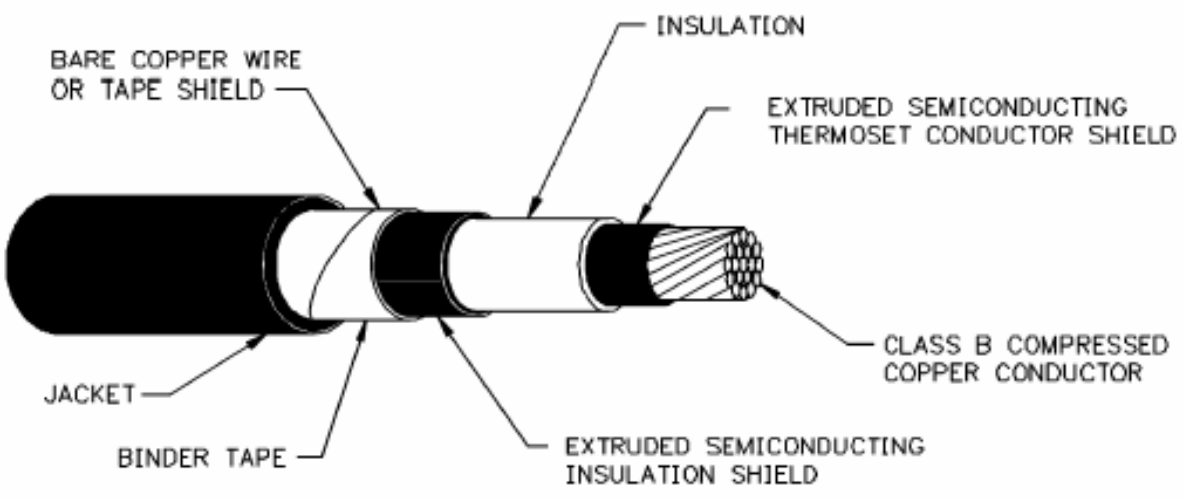


Fig. 4-13 Underground cable.

Summary

- Transmission Lines
- Parameters
- Representation
- Surge Impedance Loading
- Lumped Models
- Cables