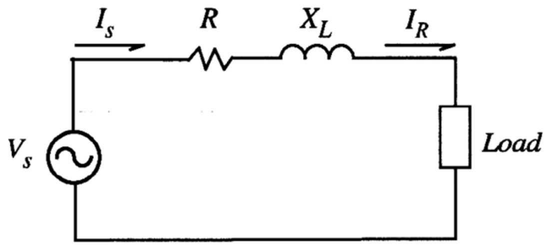
Power Flow

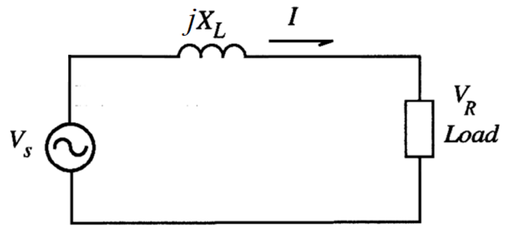
Introduction to Power Flow Studies

- **Purpose:** Analyzes the power system under normal steady-state conditions.
- **Goals:** Determine voltage (V), current (I), real power (P), and reactive power (Q).
- **Applications:**
  - Evaluate current system operation.
  - Establish benchmarks for normal operation.
  - Plan future expansions.
  - Develop contingencies for emergencies (e.g., loss of transformer, transmission line).
- **Method:** Uses non-linear analysis techniques, typically performed with software tools like ETAP®, SKM®, and Easy Power®.
- **Also Known As:** Commonly referred to as a Load Flow Study

Power Flow in a Transmission Line



Short Transmission Line Model



Simplified model with R = 0

$$S = P + jQ = VI^*$$

$$I = \frac{V_s - V_r}{jX_L}$$

$$I^* = \frac{V_s^* - V_r^*}{-jX_L}$$

$$P_s = \frac{|V_s||V_r|}{X_L}\sin\delta$$

$$P_r = -\frac{|V_s||V_r|}{X_L}\sin\delta$$

$$P_{3\emptyset,s} = 3\frac{|V_s||V_r|}{X_L}\sin\delta$$

$$P_{3\emptyset,r} = -3\frac{|V_s||V_r|}{X_L}\sin\delta$$

$$Q_s = \frac{V_s^2 - |V_s||V_r|}{X_L}\cos\delta$$

$$Q_r = \frac{V_r^2 - |V_s||V_r|}{X_L}\cos\delta$$

Power Flow

STUDY FOR FE

Real Power Flow in a Transmission Line

- **Sending-End Power** $P_{3\emptyset,s} = 3\frac{|V_s||V_r|}{X_L}\sin\delta$
- **Receiving-End Power** $P_{3\emptyset,r} = -3\frac{|V_s||V_r|}{X_L}\sin\delta$

Reactive Power Flow in a Transmission Line

- **Sending-End Reactive Power** $Q_s = \frac{V_s^2 - |V_s||V_r|}{X_L}\cos\delta$
- **Receiving-End Reactive Power** $Q_r = \frac{V_r^2 - |V_s||V_r|}{X_L}\cos\delta$

Where:
- $|V_s|$: Magnitude of sending-end voltage.
- $|V_r|$: Magnitude of receiving-end voltage.
- X_L : Line inductive reactance.
- δ : Angle between sending and receiving bus voltages.
- θ: Power factor angle (angle between receiving bus voltage and current).

- **Increasing Real Power Flow:**
- **Decrease Impedance/Inductive Reactance** X_L
- **Increase Phase Angle Difference** δ
- **Increase Voltage Magnitudes** $|V_s|$ and $|V_r|$