Substation Engineering - Power Line Carrier Communication (PLCC) (Part 1 of 2)

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Power Line Carrier Communication (PLCC) (Part 1)

- Substation Communication Needs
- Principles of PLCC
- Line Traps, Coupling Capacitors, and Line Matching Units

Agenda

- Why do Substations need to Communicate?
- What is PLCC?
- Frequency Spectrum Used
- Block Diagram of a PLCC System
- Deep Dive: Wave Trap (Line Trap)
- Deep Dive: Coupling Capacitor (CC/CVT)
- Deep Dive: Line Matching Unit (LMU)

Substation Communication Needs

- Substations are not isolated; they form a synchronized grid
- Protection (Teleprotection): Relays must communicate instantly to isolate faults on transmission lines
- Telemetry / SCADA: Central load dispatch centers need real-time data (MW, MVAR, Volts) from every substation
- Voice Communication: Operators need reliable ways to coordinate switching operations

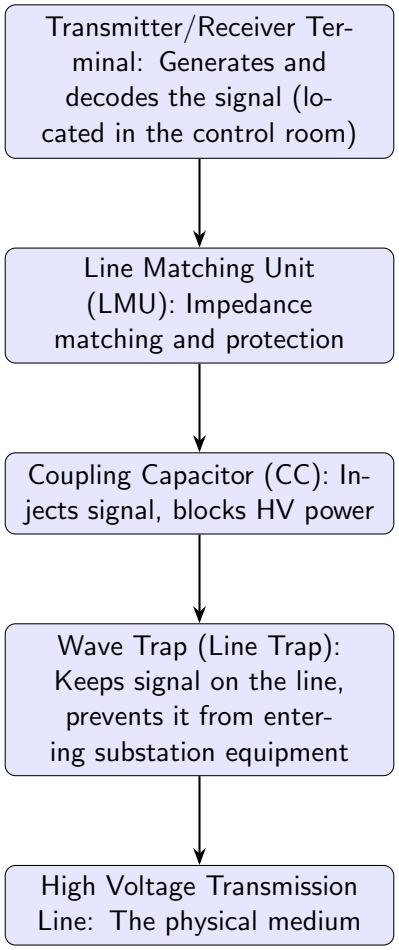
What is PLCC?

- Power Line Carrier Communication (PLCC) uses existing high-voltage transmission lines to carry communication signals
- It superimposes a high-frequency carrier signal onto the 50Hz/60Hz power frequency signal
- Cost-Effective: Eliminates the need to lay a separate, dedicated physical communication cable over vast distances
- Highly Reliable: Transmission lines are robust and rarely break compared to standard telecom cables

Frequency Range of PLCC

Parameter	Value
Power Frequency	50 Hz or 60 Hz
PLCC Carrier Frequency Range	30 kHz to 500 kHz
Bandwidth per Channel	Typically 4 kHz
Transmission Power	10W to 80W

Basic Block Diagram of PLCC



The Wave Trap (Line Trap)

- Connected in SERIES with the main transmission line at the substation entry point
- It is a parallel LC resonant circuit (Inductor and Capacitor)
- Function: Offers extremely HIGH impedance to the high-frequency PLCC signal, and negligible (LOW) impedance to the 50Hz power current
- Prevents the communication signal from 'leaking' into the substation transformers and getting grounded or attenuated

Wave Trap: Construction

- Main Coil: A heavy-duty, air-cored inductor capable of carrying the full continuous load current of the line (e.g., 2000A) and withstanding short-circuit fault currents
- Tuning Device: Capacitors and resistors that tune the trap to block specific frequency bands
- Surge Arrester: Connected in parallel across the coil to protect the tuning device from transient overvoltages (lightning)

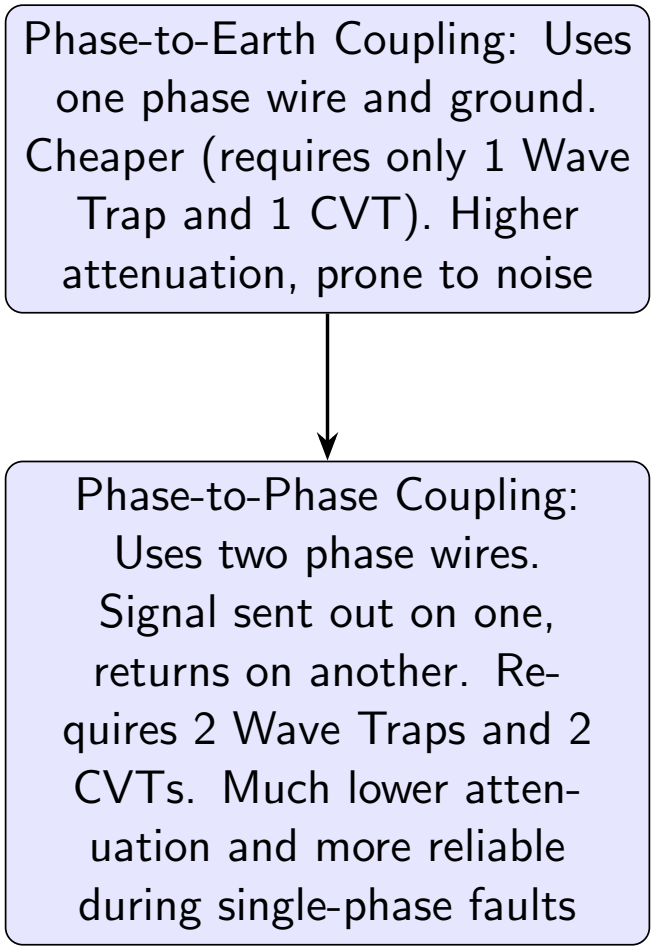
The Coupling Capacitor (CC / CVT)

- Connected in PARALLEL between the high voltage line (after the wave trap) and the ground / LMU
- Function: Acts as a high-pass filter
- Offers HIGH impedance to 50Hz power frequency (blocking high voltage from reaching electronics)
- Offers LOW impedance to high-frequency carrier signals (allowing them to pass into the line)
- Often combined with voltage measurement as a Capacitive Voltage Transformer (CVT)

Line Matching Unit (LMU)

- Placed at the base of the Coupling Capacitor
- Impedance Matching: Matches the impedance of the coaxial cable from the control room (approx 75 ohms) to the transmission line (approx 400 ohms) to maximize power transfer
- Galvanic Isolation: Uses an isolation transformer to separate control room electronics from switchyard grounds
- Drain Coil: Drains any leaked 50Hz power currents to ground safely

Coupling Arrangements



The PLCC Terminal (Indoor)

- Located inside the air-conditioned substation control room
- Houses the Modulator, Demodulator, Amplifiers, and Filters
- Takes analog voice, digital SCADA data, and simple on/off protection commands and multiplexes them into a single carrier frequency
- Connects to the outdoor LMU via a shielded high-frequency coaxial cable

Summary of Component Roles

Component	Primary Function	Location
Wave Trap	Blocks HF signal from entering substation	Series with Line
Coupling Capacitor	Passes HF signal, Blocks HV 50Hz	Parallel to Line
LMU	Impedance matching & safety isolation	Base of CVT
Terminal	Modulation and Demodulation	Control Room

Summary

- PLCC is a cost-effective and robust method for substation-to-substation communication
- It operates by superimposing a high-frequency carrier (30-500kHz) on the 50Hz power line
- The Wave Trap forces the signal down the line rather than into the local station
- The Coupling Capacitor and LMU safely inject the signal while blocking lethal voltages

Key Takeaways

- Wave Traps are parallel LC circuits that offer high impedance to PLCC frequencies.
- Coupling Capacitors leverage the property that capacitive reactance drops as frequency increases.
- LMUs are critical for impedance matching (reducing signal reflection) and operator safety.

Next Lecture Preview

- Topic: Power Line Carrier Communication (PLCC) - Part 2
- Modulation Techniques used in PLCC
- Applications: Teleprotection, SCADA, Voice
- Limitations, Noise, and Comparison with Fiber Optics (OPGW)