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

Milav Dabgar

Power Line Carrier Communication (PLCC) (Part 2)

- Modulation Techniques
- Substation Applications (Teleprotection)
- Limitations and the Future: OPGW

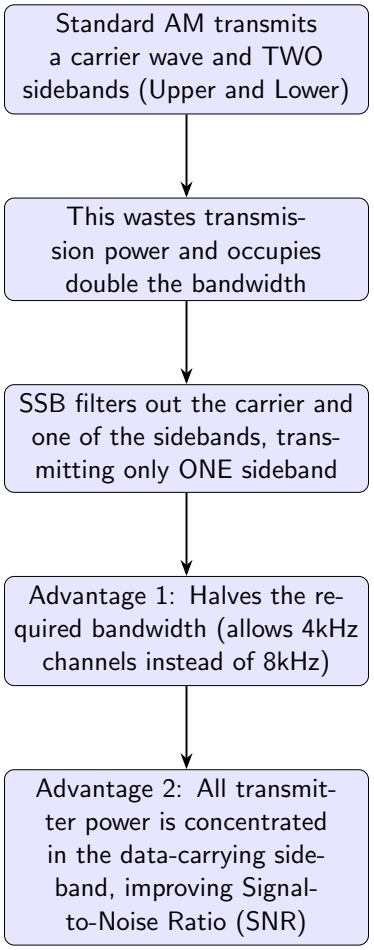
Agenda

- Recap of PLCC Hardware
- Modulation Techniques in PLCC (AM, SSB)
- Application 1: Voice Communication
- Application 2: SCADA and Telemetry
- Application 3: Teleprotection (Carrier Aided Protection)
- Limitations and Noise in Power Lines
- Comparison: PLCC vs Fiber Optics (OPGW)
- Future Trends in Substation Communication

Modulation Techniques in PLCC

- The baseband signal (voice or data) is low frequency (300Hz - 3400Hz)
- This must be modulated onto the high-frequency carrier (30kHz - 500kHz)
- Amplitude Modulation (AM) and Frequency Modulation (FM) were traditionally used
- Modern PLCC relies almost exclusively on Amplitude Modulation - Single Sideband Suppressed Carrier (AM-SSB-SC)

Why Single Sideband (SSB)?



Application 1: Voice Communication

- Provides dedicated telephone links between substation control rooms, load dispatch centers, and maintenance crews
- Independent of public telecom networks (vital during blackouts or natural disasters)
- Typically occupies the lower portion of the 4kHz channel band (e.g., 300Hz to 2000Hz)
- Operation is similar to an intercom system using Priority Calling

Application 2: SCADA and Telemetry

- Supervisory Control and Data Acquisition (SCADA)
- Transmits real-time grid data: Voltage, Current, Active Power (MW), Reactive Power (MVAR), and Breaker Status
- Allows remote control (e.g., dispatch center opening a breaker 200km away)
- Data is usually sent via Audio Frequency Shift Keying (AFSK) in the upper part of the 4kHz band (e.g., 2000Hz - 3400Hz)

Application 3: Teleprotection

- The most critical and time-sensitive application of PLCC
- Used for Carrier-Aided Distance Protection schemes
- If a fault occurs on a transmission line, relays at BOTH ends must open their breakers simultaneously
- The local relay detects the fault and sends a high-speed 'trip' or 'block' command via PLCC to the remote end relay

Teleprotection Signaling

- Because it is so critical, Teleprotection often gets its own dedicated, unshared PLCC channel
- Commands are simple: usually just a shift in frequency (FSK) to indicate 'Trip' or 'Block'
- Requires extremely high reliability and low latency (under 15-20 milliseconds)
- Must function perfectly even when the power line itself is short-circuited (which heavily attenuates the signal)

Limitations and Disadvantages of PLCC

- Limited Bandwidth: Max capability is usually a few kilobits per second (kbps). Insufficient for modern digital needs (video, heavy data, IEC 61850)
- High Noise Environment: Corona discharge, switching transients, and lightning create massive electrical noise on the line
- Attenuation: Signal strength drops significantly over long distances, requiring expensive repeater stations for very long lines
- Weather Dependent: Rain, ice, and fog increase corona noise and signal attenuation

The Alternative: Optical Ground Wire (OPGW)

- The modern replacement for PLCC in EHV networks
- Replaces the traditional steel earth wire (shield wire) at the very top of the transmission tower with a wire that contains optical fibers in its core
- Dual Purpose: Acts as a lightning shield for the power lines AND provides massive communication bandwidth
- Completely immune to electrical noise, magnetic fields, and corona discharge

Comparison: PLCC vs Fiber Optics (OPGW)

Feature	PLCC	OPGW (Fiber Optics)
Bandwidth / Speed	Low (kbps)	Extremely High (Gbps/Tbps)
Immunity to EMI	Low (prone to noise)	Total Immunity
Cost of Installation	Low (uses existing line)	High (requires new cable stringing)
Suitability for Digital Substations	Poor	Excellent (IEC 61850 standard)
Signal Attenuation	High	Very Low

Future Trends: Migration Strategies

- New EHV lines (220kV, 400kV, 765kV) are almost exclusively built with OPGW from day one
- Older lines are retrofitted with OPGW during maintenance cycles
- PLCC is rarely used for primary data in modern substations anymore, but remains highly relevant as a Backup Protection channel
- Redundancy: Utilities often use OPGW as Main-1 communication and PLCC as Main-2 for teleprotection

Summary

- PLCC utilizes SSB modulation to conserve bandwidth and maximize signal power
- Primary applications are Voice, SCADA Telemetry, and high-speed Teleprotection
- PLCC suffers from severe bandwidth limitations and susceptibility to electrical noise
- OPGW provides massive bandwidth and total EMI immunity, becoming the modern standard
- PLCC still serves a vital role as a redundant backup communication path in EHV networks

Key Takeaways

- Single Sideband (SSB) is crucial for maximizing the limited frequency spectrum of power lines.
- Teleprotection requires ultra-low latency signaling to trip breakers simultaneously across long distances.
- OPGW is replacing PLCC for data, but PLCC remains a highly cost-effective and reliable backup.

Next Lecture Preview

- Topic: Introduction to Unit 5 - Earthing and Grounding
- Importance of Substation Earthing
- Step Voltage and Touch Voltage
- Design of the Substation Earth Mat