Teleprotection Schemes and Equipment

James W. Ebrecht
Young Power Equipment
Scottsdale, AZ
Teleprotection Schemes And Equipment
Why Use Communications?

Teleprotection provides several important benefits

• Trip only the faulted line section.
• High speed simultaneous clearing for all internal line faults including end zone faults.
• Prevents overtripping on external line faults.
• Allows existing lines to transmit greater power.
• Reduces transmission line damage.
• Allows for high speed reclosing.
Teleprotection History

- AC Pilot Wire Relays
  - Short lines
- Directional Comparison with Distance Elements
  - Power Line Carrier
  - Analog Microwave
  - Audiotone
- Phase Comparison*
  - Power Line Carrier
- Current Differential and Charge Comparison*
  - Audiotone
  - Digital Channels

1935 - 1990
Relaying Communication Equipment

- **Analog Channels**
  - Analog Microwave channels
  - Leased Telephone Lines
  - Multiplexer voice channels

- **Digital Channels**
  - Digital Microwave channels
  - Leased Digital Data Service
  - Multiplexer data channels

- **Dedicated Fiber Optic Cable**
  - Singlemode Fiber
  - Multimode Fiber

- **Powerline Carrier**
  - On / Off Carrier
  - Frequency Shift Carrier

FSK Tones
Proprietary and Industry standard codes
RF Frequency coupled to Transmission line.
Pilot Wire
   Metallic cable between the substations

Voice Channels, Audiotone
   Leased telephone lines
   Analog microwave
   Analog DSO

Digital media
   CSU/DSU 2,400 bps to 56/64 kbps leased phone line
   Dedicated fiber optic pair (C37.94)
   Multiplexed digital networks (T1/SONET/MPLS)
   Communication link may be fiber, metallic or digital microwave

Spread Spectrum Radio
   Very limited use for protection signaling
Coming soon to a substation near you....
Packetized data Ethernet/IP Teleprotection

IEC 61850

From this to this
Directional Comparison Blocking

Pilot Directional Relays (PR) set to reach = 120% of protected line

Start relay (SR) is set more sensitive than Left Pilot relay

Start relay (SL) is set more sensitive than Right Pilot relay

Pilot Directional Relays (PL) set to reach = 120% of protected line

(+/-) Sta Bat

SL Relay

Transmitter

Bkr Trip

(-) Sta Bat

PL Relay

Blocking Receiver

PR Relay

Blocking Receiver

SR Relay

Bkr Trip

(+/-) Sta Bat

(-) Sta Bat
Blocking channel requirements

Operate Time:
Blocking applications require channels times between 3 to 5 msec. These times are necessary to prevent the remote terminal from “Over Tripping” on external faults.

Security:
Blocking applications require minimal security because the communication channel cannot cause a false trip.

Dependability:
Blocking applications are highly dependably because the relaying system will operate without the teleprotection channel.

Analog Channel:
Rarely used because of the slow operate times. Channels require wide bandwidth for fast operate times. Power utility may have to lease telephone channels.

Digital & Fiber Optic:
Becoming more popular because of the fast operate times, and increasing availability.

Powerline Carrier:
Most popular because of a large installed base. The power utility has complete control over the communications channel, and the equipment.
Permissive Transfer Tripping

Pilot Directional Relays (PR) set to reach = 120% of protected line

Pilot Directional Relays (PL) set to reach = 120% of protected line

(+/-) Sta Bat

PL Relay

POTT Transmitter

PL Relay

POTT Receiver

Bkr Trip

10

(-/) Sta Bat

PR Relay

POTT Transmitter

PR Relay

POTT Receiver

Bkr Trip

2

(-/) Sta Bat
Permissive channel requirements

Operate Time:
Blocking applications require channels times between 8 to 12msc. These times are necessary to allow the remote terminal to trip quickly for all internal line faults.

Security:
Permissive applications require security to prevent the channel from enabling a trip. Typical problems occur for current reversals on parallel lines.

Dependability:
Permissive applications require dependably to permit high speed clearing of both terminal. Unblock trip outputs are commonly used to enable tripping should the channel fail, coincident with a line fault.

Analog Channel:
Commonly used because they offer diverse routing. Channels require medium bandwidth to provide the required operate times.

Digital & Fiber Optic:
Becoming more popular because of the fast operate times, and increasing availability.

Powerline Carrier:
Most popular because of a large installed base. The power utility has complete control over the communications channel, and the equipment. Unblock trip output is always provided, either programmed into the relay, or the communication equipment.
Direct Transfer Tripping

(-) Sta Bat

(+)

DTT Receiver

Local Relays

Bkr Trip

(-) Sta Bat

(+)

DTT Receiver

Local Relays

Bkr Trip

(+) Sta Bat

(-) Sta Bat
Direct Transfer Trip channel requirements

Operate Time:
DTT applications require typical channels times around 12msc. These times are not as critical as Blocking, or Permissive applications, as these are backup functions.

Security:
DTT applications require very high security to prevent the channel from directly causing a false trip output.

Dependability:
DTT applications require very high dependability. This application is typically a breaker failure backup, and must operate to limit equipment damage.

Analog Channel:
Commonly used because they offer reliability due to diverse routing. Channels require medium bandwidth to provide the required operate times. Applications always use dual tones, on a dedicated channel, to provide high security.

Digital & Fiber Optic:
Becoming more popular because of the fast operate times, high security, dependability and increasing availability.

Powerline Carrier:
Most popular because of a large installed base. The power utility has complete control over the communications channel, and the equipment. Unblock trip output is never used in DTT applications.
Phase Comparison Relaying

Through load or external fault condition

External Fault Conditions

Left Terminal
Local Tx Signal

Received Signal From Right Terminal

No Trip Output

Right Terminal
Local Tx Signal

Received Signal From Left Terminal

No Trip Output

Internal Fault Conditions

Left Terminal
Local Tx Signal

Received Signal From Right Terminal

Trip Output

Right Terminal
Local Tx Signal

Received Signal From Left Terminal

Trip Output
Phase Comparison Relay Channel

Operate Time:
Phase Comparison applications require channels times around 8 ms. The channel delay should be constant, as excessive channel delay time will cause a phase shift in the composite current signal.

Security:
Single Phase Comparison applications utilize a “Blocking” philosophy, and can over trip on loss of signal. Dual phase comparison system utilize frequency shift keying, and an Unblock Trip” philosophy. This system utilizes an 150 ms unblock trip output to permit tripping upon loss of channel.

Dependability:
The single phase comparison system is more dependable because receipt of a tripping command is not required to trip the system.

Analog Channel:
Frequency shift audio tones are commonly used for this application.

Digital & Fiber Optic:
Becoming more popular because of the fast channel times, and increasing availability. Channel delay could be critical if the teleprotection is applied on a switched network.

Powerline Carrier:
On/Off Powerline carrier is used for single phase comparison systems, while FSK carrier is used for dual phase comparison systems.
Current Differential Protection

Through load or external fault condition

Internal fault condition
Current Differential channel requirements

Operate Time:
Current differential applications require channels times less then 1 msec. Excess channel delay time will cause a phase shift in the composite current signal.

Security:
Because of the large amount of data required for current differential applications, a loss of channel is more probable then a false trip. False tripping would most likely occur if the HCB operated as a over current relay, or on the independent transfer trip function.

Dependability:
Dependability is critical for current differential applications, because without communications the relay system will not operate.

Analog Channel:
Not recommended for current differential applications, because of the excessive channel delay times.

Digital & Fiber Optic:
Becoming more popular because of the fast channel times, and increasing availability. Channel delay is critical and must be calculated for each channel routing.

Powerline Carrier:
Powerline carrier is never used for current differential applications because the channel may be corrupted and unavailable when the line is faulted.
Effects of channel delay on Current Differential Protection

Through load or external fault condition

<table>
<thead>
<tr>
<th>0° Phase Shift</th>
<th>90° Phase Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Channel Delay</td>
<td>4 msec Channel Delay</td>
</tr>
</tbody>
</table>

- Left Terminal Local Signal
- Right Terminal Received Signal
- Differential Current

Diagram showing the effects of channel delay on current differential protection.
## Channel Delay

### Fault Recognition Time and Fault Clearance Time

<table>
<thead>
<tr>
<th>Protection Equipment</th>
<th>Teleprotection Transmitter</th>
<th>Telecommunication Circuit and/or Link</th>
<th>Teleprotection Receiver</th>
<th>Protection Equipment</th>
<th>Circuit-Breaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fault Recognition Time</td>
<td>Time for Initiating Command</td>
<td>Time for Propagation Time, 0 - 5 ms</td>
<td>Selection and Decision Time, 1 - 40 ms, Relay Included</td>
<td>Additional Delay Due to Noise, 0 - 20 ms</td>
<td>Relay Decision Time, 0 - 10 ms</td>
</tr>
<tr>
<td>10 - 30 ms</td>
<td>1 - 5 ms</td>
<td>1 - 40 ms</td>
<td>0 - 20 ms</td>
<td>0 - 10 ms</td>
<td>30 - 80 ms</td>
</tr>
</tbody>
</table>

- **Nominal Transmission Time**: To 2 - 45 ms
- **Maximum Actual Transmission Time**: 2 - 65 ms
- **Overall Channel Operating Time**: 2 - 65 ms
- **Fault Clearance Time**: To 2 - 45 ms
- **Time for Initiating Command**: 1 - 5 ms
- **Time for Propagation**: 0 - 5 ms
- **Selection and Decision Time**: 1 - 40 ms, Relay Included
- **Additional Delay Due to Noise**: 0 - 20 ms
- **Operating Time**: Including Arcing Time, 30 - 80 ms

*Note: Propagation time not included.*
Types of Communications, Channels and Circuits
SONET

Synchronous Optical Network

Commonly referred to and notated as OC3, OC12, OC48 etc.

OC1 = 28 T1
**WHAT IS SONET?**

**Synchronous Optical NETwork**

A Global Standard for Optical Signals for Communications
- American National Standards Institute (ANSI)
- Telcordia which was Bell Communications Research (Bellcore)
- International Telecommunications Union (ITU)

**Motivation:** An Open Systems Optical Architecture for Multi-vender Interworking
T1 Channel Bank

T1 MUX

OPX
OPX
OPX
DTT
DCB
HCB
DATA

T1 LINK

T1 MUX

OPX
OPX
OPX
DTT
DCB
HCB
DATA
Channel Delay Time over T1 Multiplexer

Sample Channel Delay Calculation

Delay into T1 Channel = 187.5 us.
4 Miles Optical Fiber delay @ 8.0 us./mile = 32.0 us.
* Delay through one Drop & Insert Terminal = 25.0 us.
Delay out of T1 Channel = 187.5 us.
Total delay time = 432.0 us.

* Note:
Systems utilizing Digital Access and Cross-connect (DACS) units will incur a 250us delay going into and out of each DACS.
Digital Circuits and Equipment

Proprietary Circuits and Equipment:
SEL Mirrored Bits, 421
RFL Digital, 9745, GARD8000
GE Digital, N60
Iniven Digital, PRU2000

Non-Proprietary Circuits and Equipment:
IEC 61850 and device
C37.94 interfaces
Audio Circuits or Paths
What is an Audio Circuit?

300 to 3,400 Hertz

Digital or Analog Microwave

A VF DSO on a channel bank
Analog Voice Channel Frequency Allocation

Frequency Group 3
(+/- 75 Hz. Shift)
- Trip A = 1540 Hz.
- Guard A = 1690 Hz.
- Guard B = 1880 Hz.
- Trip B = 2030 Hz.

Frequency Group 5
(+/- 75 Hz. Shift)
- Trip A = 2220 Hz.
- Guard A = 2370 Hz.
- Guard B = 2560 Hz.
- Trip B = 2710 Hz.
FSK Keying

Basic function is a change of frequency to change trip output status

Tones are linear and do not contain data

Receiver monitors tones for proper timing and freq. shift
Orthogonal Audio Keying

Digital Data over Audio

OFDM Protocol

Operates at 6.6 Kbps

22 simultaneous tones

Uses entire Audio Frequency band (300Hz - 3200Hz)
• Narrow bands at different frequencies transmit digital data
• Phase comparison to send 2 bits per tone
• Synced using pilot tones
Powerline Carrier
Powerline Carrier

Transmission Line Communications Medium

**Advantages:**

1. The powerline offers a robust medium that is designed for reliable service.
2. The powerline is under the complete control of the utility.
3. The powerline originates, and terminates at the desired locations.

**Disadvantages:**

1. Increased signal attenuation may occur at the time of the fault.
2. Noise levels may increase at the time of the fault.

The powerline carrier signal must be coupled to the transmission line with expensive line tuning equipment.
Typical two terminal line, powerline carrier system

Powerline Carrier System Components

- Transmission Line
- Line Tuners
- Coupling Capacitors
- Line Traps
- RF Hybrids
- PLC Transmitter, and Receiving equipment
- Interconnecting coaxial cables
Typical two terminal line, powerline carrier system
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