Relay Communications Basics
List of important jobs in the Substations

4th IT department
3rd Comms Techs
2nd Substation Techs
1st Relay Techs

4th IT department
3rd Relay Tech
2nd Substation Techs
1st Comms Techs

Depends on who I’m talking to....

We are all important in the process of keeping the power on....

All of these Jobs have one thing in common

Communications
Overview of the Substation

- **Protective Relay**
  - 87L
  - Distance Relay

- **Teleprotection Device**

Inputs & Outputs

Status/Control Information Must get to Operation
Comms Network/Channel

Questions ask of you...Relay Tech
1. What type of Comms channel is the Relay communications operating over?
2. How can I determine what type of Comms channel does the relay uses?
3. How can I use the Comms channel to help me determine if the Relay is working correctly?
4. How will I know if it is the Relay or the Comms channel that is causing the problem?

Comms Tech...Might ask?
1. How does the relay channel get across the Network?
2. What points can I check to see where the channel is being lost?

Does Anyone Have a Cell Phone?
What is a Connection???

Radio Connection

Cellular Communication
Cellular Network

Mobile Phone

WiFi

WiFi Enabled Laptop

NOW

Before/Now

Wire Connection

Cell Phones that connect the world

Telephone Company Wiring

Demarcation Point

HOUSE

Wire Distribution Device

Telephone Protector
Relay Communication Basics

The Basic Relay Tech Guide to Communication

- Why?
- Terms
- Equipment
- Connections
- Troubleshooting
Why Use Communications?

- Trip only the faulted line section.
- High speed simultaneous clearing for all internal line faults including end zone faults.
- Prevents over-tripping on external line faults.
- Reduces transmission line and related equipment damage.
- Allows for high speed reclosing.

Must have Communications to keep things operating properly
Typically the relay will either have its own Comms channel or be connected to a Communication device such as a Teleprotection (TPR) chassis which will be used as the Communication channel. In all cases, it will most likely have a 64Kbps channel it operates over, and will be inserted into a network at some point.
Although the last slide displays a fiber network, there could be other types of Communication Present.

- Microwave radios
- Digital Service Lines
- FSU (Fiber Service Units)
- Plain old telephone line
Good to Know Comms TERMS for Relay Techs?

DS0-Channel module 64Kbps audio/digital

• **Audio Channel**
  A communications channel using discrete analog signals to carry information, the signals can be simple *on or off*, **FSK** (two or more frequencies), *modulated*. i.e. Audio TPS, Telephone (POT), Music on the radio, using voice frequency 300-4000 Hz (Audio) 30 kHz to 500 kHz (PLC) even a laser LEDs can carry audio signals. 2-Wire vs. 4wire

• **Amplitude Modulated**
  Amplitude modulation (AM) is a modulation technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. AM works by varying the strength (amplitude) of the carrier in proportion to the waveform being sent. That waveform may, for instance, correspond to the sounds to be reproduced by a loudspeaker.

  \[ \text{PLC=Basically means ON for transmit and receive and Off or no data. i.e PLC (Power Line Carriers)} \]

• **Frequency Modulation**
  In telecommunications and signal processing, frequency modulation (FM) is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave.
**PCM**

Pulse-code modulation (PCM) is a method used to digitally represent sampled analog signals. *It is the standard form of digital audio in computers*, Compact Discs, digital telephony and other digital audio applications. In a PCM stream, the **amplitude** of the analog signal is sampled regularly at uniform intervals, and each sample is quantized to the nearest value within a range of digital steps.
• **A to D Convertor**

A device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude. i.e. Telemetry over Multiplexer

• **D to A Convertor**

A device that converts a bit stream (1 & 0) to an Analog waveform
• **FSK**

(Frequency Shift Keying) means just what it said, shifting from one frequency to another to send and receive data. (2F and 3F) (a form of FM Modulation) Dial or Leased line modules.

![Diagram showing FSK signal transmission and guard trip](image)
Good to know Terms cont.

**Standards of sending messages**

- **Asynch Comms**

  (Asynchronous) Uses start and stop and parity is *serial communications*. **No Clock**. (RS232), Protocol standard = 8,N,1 9600 bps (baud rate) MB = 1 Start, 6 Data, 1 Parity, 1 Stop = 9 Bits, MB8 = 1 Start, 6 Data, 1 Parity, 2 Stop = 10 Bits (SEL)

  **8N1** = 1 Start, 8 Data, 1 Stop = 10 Bits (same as MB8)
  **8E1/8O1** = 1 Start, 8 Data, 1 Parity, 1 Stop = 11 Bits
  **8E2/8O2** = 1 Start, 8 Data, 1 Parity, 2 Stop = 12 Bits
  **6O1** = 1 Start, 6 Data, 1 Parity, 1 Stop = 9 Bits (same as MB
  **6O2** = 1 Start, 6 Data, 1 Parity, 2 Stop = 10 Bits (same as MB8 and 8N1 and 8N1)

**DTE vs. DCE Asynchronous**

The term **DTE Data Terminal Equipment** is used to describe the initiator or controller of the serial connection, typically the computer. A PLC is defined as a DTE device.

The term **DCE Data Communications Equipment** describes the device that is connected to the DTE device such as a modem. The terms are most often used in reference to serial communications defined by the EIA RS232 standard.
- **Synchronous Comms**

  (Synchronous) A single Clock source is required for all communications. Data errors can be manifested on the end order errors will cause relay Comms drops i.e ROK Fail

  **Clock is necessary for all communications**

  **Asynchronous vs. Synchronous**
<table>
<thead>
<tr>
<th>Good to know Terms cont.</th>
<th>Misc. terms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A-synch to Synch convertor</strong></td>
<td>Device that converts A-synch data to Synch data.</td>
</tr>
<tr>
<td><strong>Fiber to RS232 convertor</strong></td>
<td>Allows fiber connect to Relay and RS232 connection to Communication device (MUX)</td>
</tr>
<tr>
<td><strong>Loop-Back testing</strong></td>
<td>Method of determining the proper operation of a device of Comms link.</td>
</tr>
<tr>
<td><strong>Addressing</strong></td>
<td>A means of providing additional security for a relay channel by insuring the local and remote terminals addresses match before allowing equipment to function i.e. TX 001, RX 002 (Local) TX 002, RX 001 (Remote)</td>
</tr>
<tr>
<td><strong>Digital /Analog Channel</strong></td>
<td>Is the physical transfer of data over a point-to-point or point-to-multipoint communication channel. Examples of such channels are copper wires, optical fibers, wireless communication channels, storage media and computer buses. The data are represented as an electromagnetic signal, such as an electrical voltage, radio-wave microwave, infrared signal or light pulses.</td>
</tr>
</tbody>
</table>
Good to Know Comms TERMS For relay Techs? Cont.

Types of transport Hardware

- **Channel Bank**
  A Device that carries multiple analog or digital signals between sites. The Analog and Digital channels are converted to a **64 Kbps** channels and known as a **DS0**, then multiplexes into a higher speed channel at **1.54 Mbps** using a method of Time Division Multiplexing known as **DS1**. Then transported as a block to the remote terminal(s) where they are De-multiplexed and passed back to the DS0 or channel modules. Usually, the digital information is put on each DS0 signal using pulse code modulation (PCM).

- **Multiplexer**
  A multiplexer (or mux) is a device that selects one of several analog or digital input signals and forwards the selected input into a single line. Multiplexers are mainly used to increase the amount of data that can be sent over the network within a certain amount of time and bandwidth. Generally communicates via Electrical, DSU or fiber, or microwave radio.
Typically the relay will either have its own Comms channel or be connected to a Communication device such as a Teleprotection (TPR) chassis which will be used as the Communication channel. In all cases, it will most likely have a 64Kbps channel it operates over.
Types of transport systems

- **Multiplexer** Channel Bank

A multiplexer (or mux) is a device that selects one of several analog or digital input signals and forwards the selected input into a single line. Multiplexers are mainly used to increase the amount of data that can be sent over the network within a certain amount of time and bandwidth. Generally, they communicate via Electrical DSU or fiber, or microwave radio.
A **DACS** allow the **Multiple DS1** to be disassembled, giving the user access to the DS0. The user can then insert the DS0 into other DS1 signals.
Channel Banks cont.

- **T1 Channel Bank (IMUX, Focus)**
  - Operates at 1.54 Mbps
  - Fiber or Electrical connections,
    - Sometimes T1 connect will be used with DSU (digital service unit) at 64 Kbps
- **Microwave**
  - Operates at roughly 1.0 gigahertz (GHz) to 30 GHz
  - Large towers to point to point radios
  - Much of the industry use point to point radios.
- **Sonnet (Synchronous Optical Network)**
  - Operates at 155.520 megabits per second (Mbit/s).
  - Packet-oriented data transmission
- **Ethernet**
  - Is a family of computer networking technologies for local area (LAN) and larger networks.
  - Systems communicating over Ethernet divide a stream of data into shorter pieces called frames. Each frame contains source and destination addresses and error-checking data so that damaged data can be detected and re-transmitted.
  - Operates at 10 Mbit/s, 100 Mbit/s, and 1 Gbit/s, respectively
### NORTH AMERICAN ELECTRICAL DIGITAL HIERARCHY

<table>
<thead>
<tr>
<th>CHANNEL</th>
<th>BIT RATE</th>
<th>COMPOSITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS3 *</td>
<td>44.736 Mbps</td>
<td>28 DS1 (672 voice channels)</td>
</tr>
<tr>
<td>DS2</td>
<td>6.312 Mbps</td>
<td>4 DS1 (96 voice channels)</td>
</tr>
<tr>
<td>DS1C</td>
<td>3.152 Mbps</td>
<td>2 DS1 (48 voice channels)</td>
</tr>
<tr>
<td>DS1</td>
<td>1.544 Mbps</td>
<td>24 DS0 (24 voice channels)</td>
</tr>
<tr>
<td>DS0</td>
<td>64 Kbps</td>
<td>DS0 (1 voice channel)</td>
</tr>
</tbody>
</table>

* - DS3 is the same as OC1 or SONET.

OC3 = 3 * DS3 = 84 T1 circuits!
**OC - Optical Carrier**

Transport levels defined for SONET

Your Relay is connected Here

**DS0 = 64kbps**

MUX is connected Here

**DS-1 = 24 DS0 = 1.544Mbps**

<table>
<thead>
<tr>
<th>OC-1</th>
<th>51.84Mbps : 1 DS-3, <strong>28 DS-1, 672 DS-0</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>OC-3</td>
<td>155.52Mbps : 3 DS-3, <strong>84 DS-1, 2016 DS-0</strong></td>
</tr>
<tr>
<td>OC-9</td>
<td>466.56Mbps : 9 DS-3, <strong>252 DS-1, 6048 DS-0</strong></td>
</tr>
<tr>
<td>OC-12</td>
<td>622.08Mbps : 12 DS-3, <strong>336 DS-1, 8064 DS-0</strong></td>
</tr>
<tr>
<td>OC-18</td>
<td>933.12Mbps : 18 DS-3, <strong>504 DS-1, 12096 DS-0</strong></td>
</tr>
<tr>
<td>OC-24</td>
<td>1244.16Mbps : 24 DS-3, <strong>672 DS-1, 16,128 DS-0</strong></td>
</tr>
<tr>
<td>OC-36</td>
<td>1866.24Mbps : 36 DS-3, <strong>1008 DS-1, 24,192 DS-0</strong></td>
</tr>
<tr>
<td>OC-48</td>
<td>2488.32Mbps : 48 DS-3, <strong>1344 DS-1, 32,256 DS-0</strong></td>
</tr>
<tr>
<td>OC-96</td>
<td>4976.64Mbps : 96 DS-3, <strong>2688 DS-1, 64,512 DS-0</strong></td>
</tr>
<tr>
<td>OC-192</td>
<td>9953.28Mbps : 192 DS-3, <strong>5376 DS-1, 129,024 DS-0</strong></td>
</tr>
</tbody>
</table>

Your Relay is connected Here

MUX is connected Here
Protective Relay

Substation/Plant

Protective Relay

Substation/Plant

Typically the relay will either have its own Comms channel or be connected to a Communication device such as a Teleprotection (TPR) chassis which will be used as the Communication channel. In all cases it will most likely have a 64Kbps channel it operates over.
Relaying Communication Channels

- **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**
  - Single mode Fiber
  - Multimode Fiber

- **Short Haul Fiber**
  - C37.94

- **Intra-Sub LAN**
  - 61850

- **Power-line Carrier**
  - On / Off Carrier
  - Frequency Shift Carrier
  - SSB
Analog Channels

Analog Microwave channels

- i.e. Voice Channels, Video, Data
  - Parabolic antenna
  - Point to Point/Narrow Beam
  - Alignment is important
  - Advantage
    - the high frequency of microwaves gives the microwave band a very large information-carrying capacity; the microwave band has a bandwidth 30 times that of all the rest of the radio spectrum below it
  - A disadvantage
    - is that microwaves are limited to line of sight propagation; they cannot pass around hills or mountains as lower frequency radio waves can.
  - Weather

Leased Telephone Lines

- A leased line is a service contract between a provider and a customer, whereby the provider agrees to deliver a symmetric telecommunications line connecting two or more locations in exchange for a monthly rent (hence the term lease). It is sometimes known as a "private circuit"
  - 2X pair of copper twisted wires (TX/RX)
  - a leased line is always active, (meaning no service interruptions due to Phone company testing)
  - In the U.S., low-speed leased lines (56 kbit/s and below) are usually provided using analog modems.
  - Generally ordered with specified attenuation. (i.e. 10db)
Analog Channels

- **Multiplexer voice channels**
  - Much like a leased line, but is generally part of a company's Comms system.
  - Terminal Block connection type
  - 2 or 4 wire
  - Part of Channel Bank traffic/meaning that it is not a stand alone circuit and must relay on additional hardware.

Digital Channels

Digital Microwave channels

- i.e. Voice Channels, Video, Data
  - Parabolic antenna
  - Point to Point/Narrow Beam
  - Alignment is important
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    - is that microwaves are limited to line of sight propagation; they cannot pass around hills or mountains as lower frequency radio waves can.
  - Weather
Digital Channels

Leased Digital Data Service

Back in the 1950’s, 1960’s and 1970’s a leased line meant a hotline, dedicated old-fashioned analogue telephone line, linking two sites.

However for the past few decades the phrase has come to mean a fixed bandwidth dedicated symmetric digital connection between two sites.

So when people talk of a leased line, they almost always mean a digital leased line. Usually, they mean a point-to-point Ethernet circuit.

Digital leased lines offer a number of benefits. Their connection speeds are fixed, so your connection won’t slow down at peak times. They’re symmetric, so you’re more likely to have adequate bandwidth for applications such as telephony, FTPing files, and loading files from a server on another site (and saving them).

The costs of a digital leased line keep falling, as the UK telecoms networks are upgraded, the increased network usage leads to economies of scale. Much of the network makes use of fiber-optic cable. Upgrading it doesn’t usually require that new fibre be laid, just that the equipment at the ends of the fibres be upgraded. It’s not just computers that have been getting faster and cheaper. Networking equipment has to, and this has made it possible to provide digital leased lines for ever smaller monthly fees.
Dedicated Fiber Optic Cable

- **Single mode Fiber**
  - *In fiber-optic communication, a single-mode optical fiber (SMF) is an optical fiber designed to carry light only directly down the fiber*

- **Multimode Fiber**
  - Cable has a little bit bigger diameter, with a common diameters in the 50-to-100 micron range for the light carry component (in the US the most common size is 62.5um). Most applications in which Multi-mode fiber is used, 2 fibers are used (WDM is not normally used on multi-mode fiber). POF is a newer plastic-based cable which promises performance similar to glass cable on very short runs, but at a lower cost.

- **Multimode fiber**
  - Gives you high bandwidth at high speeds (10 to 100MBS - Gigabit to 275m to 2km) over medium distances. Light waves are dispersed into numerous paths, or modes, as they travel through the cable's core typically 850 or 1300nm.
  - Typical multimode fiber core diameters are 50, 62.5, and 100 micrometers. However, in long cable runs (greater than 3000 feet [914.4 meters), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission so designers now call for single mode fiber in new applications using Gigabit and beyond.
**Dedicated Fiber Optic Cable**

**Short Haul Fiber**
- C37.94 full title *IEEE Standard for N Times 64 Kilobit Per Second Optical Fiber Interfaces Between Teleprotection and Multiplexer Equipment*, is an IEEE standard that defines the rules to interconnect Tele-protection and multiplexer devices of power utility companies. The standard defines a data frame format for optical interconnection, and references standards for the physical connector for multi-mode optical fiber. The standard also defines behavior of connected equipment on failure of the link, and the timing and optical signal characteristics. The standard was published in 2002.

**Intra-Sub LAN 61850**
- IEC 61850 is a standard for the design of electrical substation automation. IEC 61850 is a part of the International Electrotechnical Commission's (IEC) Technical Committee 57 (TC57)[1] reference architecture for electric power systems. The abstract data models defined in IEC 61850 can be mapped to a number of protocols. Current mappings in the standard are to MMS (Manufacturing Message Specification), GOOSE, SMV (Sampled Measured Values),[clarification needed] and soon to Web Services. These protocols can run over TCP/IP networks or substation LANs using high speed switched Ethernet to obtain the necessary response times below four milliseconds for protective relaying.
The Relay Connections

- Typically the relay will either have its own Comm channel or be connected to a Communication device.

- A Teleprotection (TPR) chassis may be used as the Communication channel.
  - In these cases, the relay will be connected via outputs to inputs, or via 61850.

- In most cases, it will use a single DS0 (64Kbps) channel and is carried over a Multiplexer or a Microwave channel bank.

- Exception maybe the Audio 2/4-wire connection.

Protective Relay

- POT (Audio Tone) 2/4-wire
- Electrical Direct RS232/449/v.35
- Fiber Direct 1300/1550 NM SM/MM
- SHFI 850 NM

Solutions for an evolving world.
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Audio Tone Connections, Relay to Relay, Relay to MUX

- Analog phone lines are still used for many applications, where this is the only means of communication available. i.e. Utility to Co-Gen...

- These lines can be 2-wire or 4-wire connections. In 2-wire all information TX and RX is sent and received over 2 wires. In 4-wire there will be 2-pairs TX and RX. (never shall the two meet)

- Typically TX and RX will be cross-connected.

- There may be a direct wire connection via the local phone company, or private network. Additionally, the 2/4wire connection may use a MUX channel, and the connection will be to a 2/4-wire E&M module w/RJ11 or terminal block connection to the rear interface of the MUX chassis.

- This form can be determined by the type of connections on the equipment chassis or, *If it terminates into a TELCO Punch down block or a MUX chassis.*

- Testing of the relay can be done via looping at any of the TX/RX connections.

- In most cases Addressing is not required for security, if used over a leased line, but may be required over a MUX channel. If used, it will need to be disabled during loop testing.
Direct Fiber Connections, Relay to Relay

- Typically each substation house will have a patch panel that will connect the outside fiber to the insider fiber.
- The patch panel will provide a place to loop inside fiber for loop testing of relay.
- This form can be determined by the type of fiber and the connections. *If there is a patch panel this will be direct fiber.*
- Testing of the relay can be done via looping at any of the TX/RX connections.
- In most cases Addressing is not required for security, but if used it will need to be disabled during loop testing.
Protective Relay

SHFI 850 NM (Short Haul Fiber Interface)

MUX or Channel Bank

Electrical, microwave
Radio or Fiber

SHFI 850 NM (Short Haul Fiber Interface)

Protective Relay

Short Haul Fiber/MUX

- The MUX/CHBNK will have a Synchronous module w/SHFI installed.
- Requires a single clock to operate
- The channels will operate at 64Kbps, this is many times referred to as **C37.94**, which a standard defining the parameter of the channel.
- This form can be determined by the type of fiber and the connections. **If the fiber terminates into a channel bank or MUX it will be a SHF connection.**
- Testing of the relay can be done via looping at any of the TX/RX connections. But many times the SHFI will not have an available clock and must use the clock of the MUX/CHBNK to operate.
- In most cases Addressing is required for security, but if used it will need to be disabled during loop testing.
Protective Relay

Synchronous Electrical Interface’s/MUX

- The MUX/CHBNK will have a Synchronous module w/Elect (D/Shell) installed.
- Requires a single clock to operate, much like the SHFI.
- The channels will operate at 64Kbps, this is many times referred to as C37.94, which a standard defining the parameter of the channel.
- This form can be determined by the type of connections. 
  
  *If the cable terminates into a channel bank or MUX it will be a ELECT/MUX connection.*
- Testing of the relay can be done via looping at any of the TX/RX connections. Many times these types of connections will not have an available clock and must use the clock of the MUX/CHBNK to operate.
- In most cases Addressing is required for security, but if used it will need to be disabled during loop testing.

Many forms RS449 (37pin) v.35

Electrical, \(\mu\)wave Radio or Fiber

Many forms RS449 (37pin) v.35
Asynchronous Electrical Interface’s/MUX RS232

- The MUX/CHBNK will have a Asynchronous module w/Elect (9-PinD/Shell) installed.
- No clocking is required at the equipment level.
- Word Length/Baud rate/Start and Stop pits must be defined.
- The MUX channels is still operating at 64Kbps, although the RS232 channel using only a portion of the 64K channel. Many times multiple channel can run over a single time slot. (sub rate)
- This form can be determined by the type of connections.
- If the cable terminates into a channel bank or MUX it will be a ELECT/MUX connection.
- Testing of the relay can be done via looping at any of the TX/RX connections .
- In most cases Addressing is required for security, but if used it will need to be disabled during loop testing.
- RS232 Loopback plug, which connects the TX pin with the RX pin is a helpful tool.
• Optical Source 850 nm (infrared) VCSEL transmitter Typical transmit level — 12.0 dBm Maximum output level — 3.0 dBm

• Power Requirements Receives adequate power from a single EIA-232 TXD data line connected to Pin 3 of the DB-9 connector. Additionally, the SEL-2812 accepts power applied to Pin 1, 7, or 8.

Asynchronous Electrical Interface’s/MUX

RS232 to Fiber

- Word length
- Baud Rate
- Start/Stop Bits

8N1 = 1 Start, 8 Data, 1 Stop = 10 Bits (same as MB8)
8E1/8O1 = 1 Start, 8 Data, 1 Parity, 1 Stop = 11 Bits
8E2/8O2 = 1 Start, 8 Data, 1 Parity, 2 Stop = 12 Bits
6O1 = 1 Start, 6 Data, 1 Parity, 1 Stop = 9 Bits (same as MB)
6O2 = 1 Start, 6 Data, 1 Parity, 2 Stop = 10 Bits (same as MB8 and 8N1 and 8N1)

Protective Relay
Teleprotection Channel

- MUX or Channel Bank
- Electrical, microwave, Radio or Fiber
- Direct Fiber
- SHFI
- Electrical Connection Multiplexer
- POT (Audio Tone)
- Microwave (A or D) Direct
- Ethernet

- Tele-Protection Relay
- Relay Output

- Comms Channel

- Protective Relay
Teleprotection Channel

**Power-line Carrier**
- On / Off Carrier
  - DTT, POTT, DCUB, DCB
- Frequency Shift Carrier
  - DTT, POTT, DCUB, DCB
- SSB
  - Voice Data channel

**Flavors**
- Transmitter and Receiver
  - Transmitter only
  - Receiver only
- RFL
- SEL
- ABB
- GE

**Hybrids ?**
- Inside Station
- BUS ISOLATION (dB)
- DTT, POTT, DCUB, DCB
- CCVT Coupling Cap
- Underground Coax
- Line Trap
- Power line
- Relay
- TX/RX
- Hard wired to Input
- PLC Equip
- Voice/Data
- To remote Terminal
Ethernet Communications

Figure 3-3. Typical Network Application
Ethernet Communications

Multiple Types of Interfaces on the rear

- Synchronous
- Asynchronous
- 2/4 wire
- Fiber

RTU
RS-232
RS-422
Protection Relay
Protection Relay
T1/E1 Multiplexer
T1
SCADA Master

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