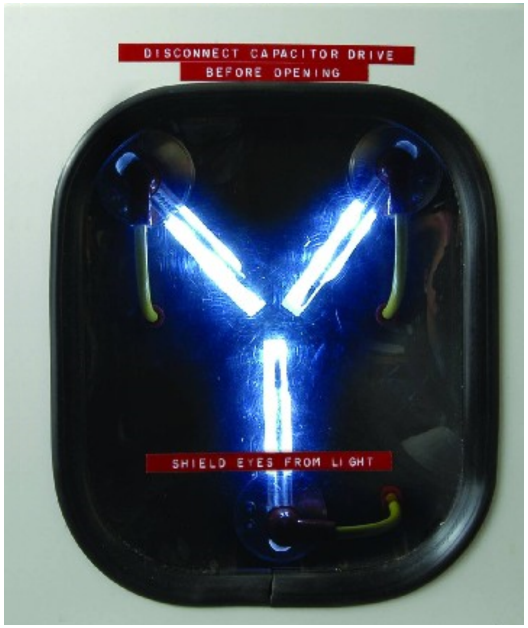
WHY INDUSTRY NEEDS TIME

A POWER INDUSTRY CASE STUDY



Aaron Martin

The Bonneville Power Administration

Bonneville Power Adminstration

Introduction

Bonneville Power Administration Background

Power System Transmission Applications that require Precise Time

Examples of Power System Applications Affected by Precise Timing errors.

BPA Plan's for Communication Infrastructure

BONNEVILLE POWER ADMINISTRATION

Bonneville Power Adminstration

General Information

BPA established	1937
Service area size (square miles)	300,000
Pacific Northwest population	12,922,668
Transmission line (circuit miles)	15,169
BPA substations	260

BPA SERVICE TERRITORY

BPA SERVICE TERRITORY

Transmission System

Operating voltage	Circuit miles
1,100 kV	1
1,000 kV	264[8/]
500 kV	4,707
345 kV	570
287 kV	229
230 kV	5,326
161 kV	119
138 kV	56
115 kV	3,496
below 115 kV	282
Total[9/]	15,050

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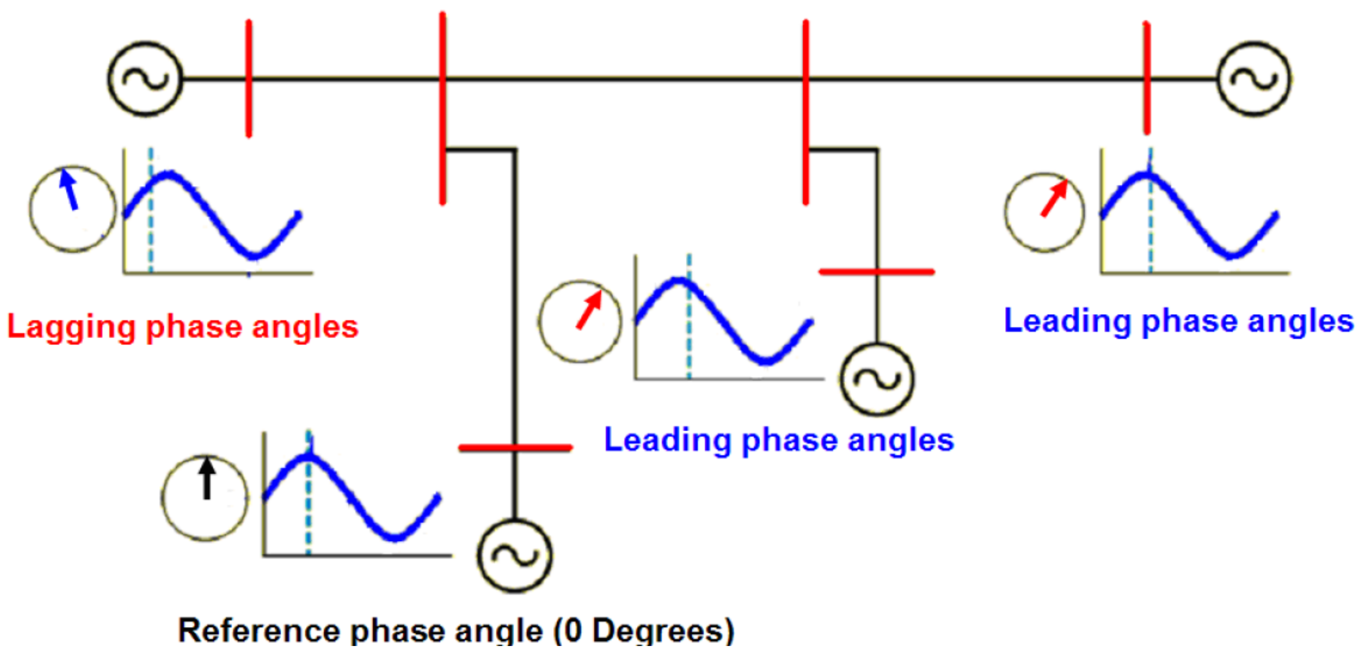
Power System Transmission Applications that Require Precise Time

- Phasor Measurement Units
- Line Differential Protection
- Traveling Wave Fault Location
- System Event Recordings
- Substation Local Area Networks

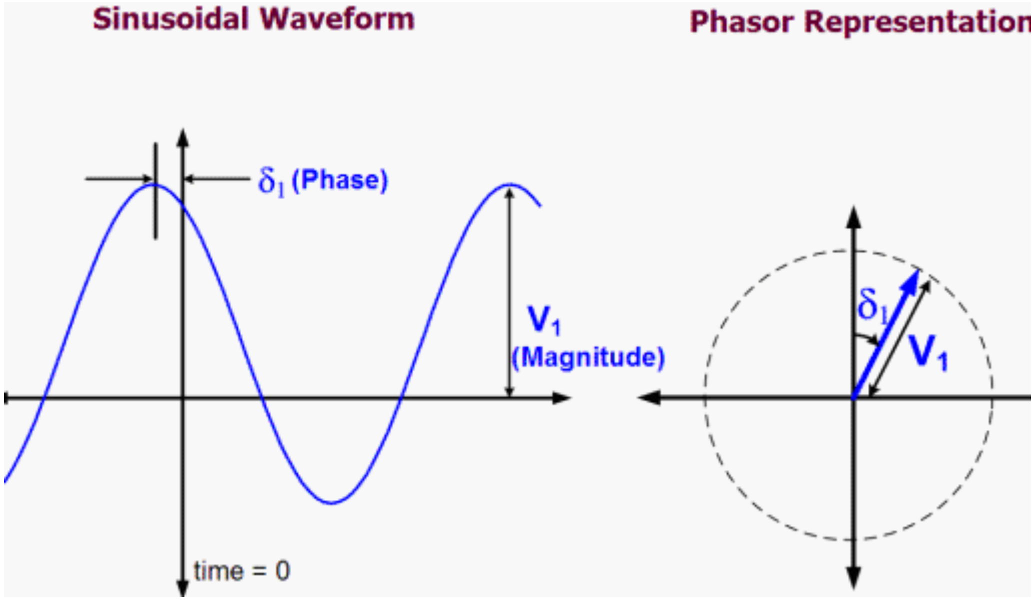
PHASOR MEASURMENT UNITS or SYNCROPHASORS

- **PMUs** Synchro-phasors, or Phasor Measurement Units (PMUs), are synchronized measurement systems that provide information on phasor angles and frequency at different power system locations.



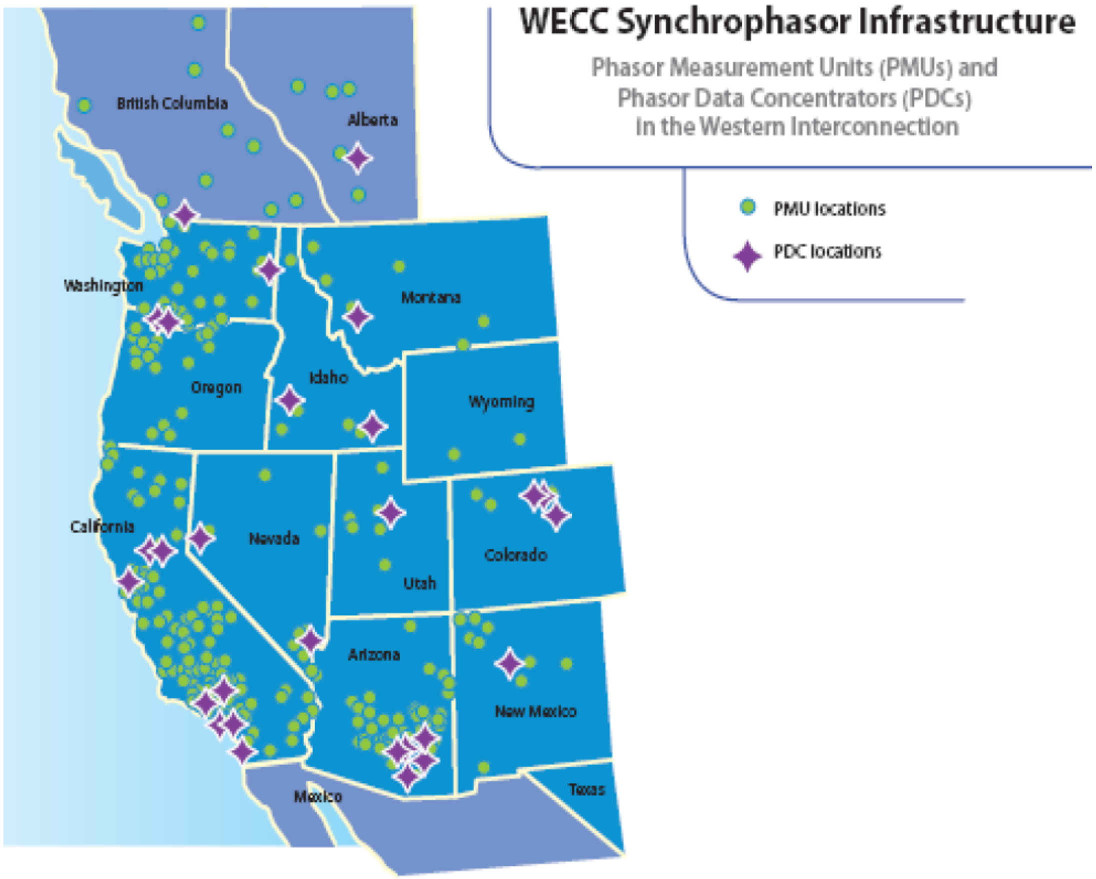
PHASOR MEASURMENT UNITS or SYNCROPHASORS

- **Why 1 micro-second accuracy requirement?**
  - **Power System frequency = 60Hz**
    - **One period or 360 degrees = 16.6ms**
    - **0.25 degrees = 11.5 micro-seconds**



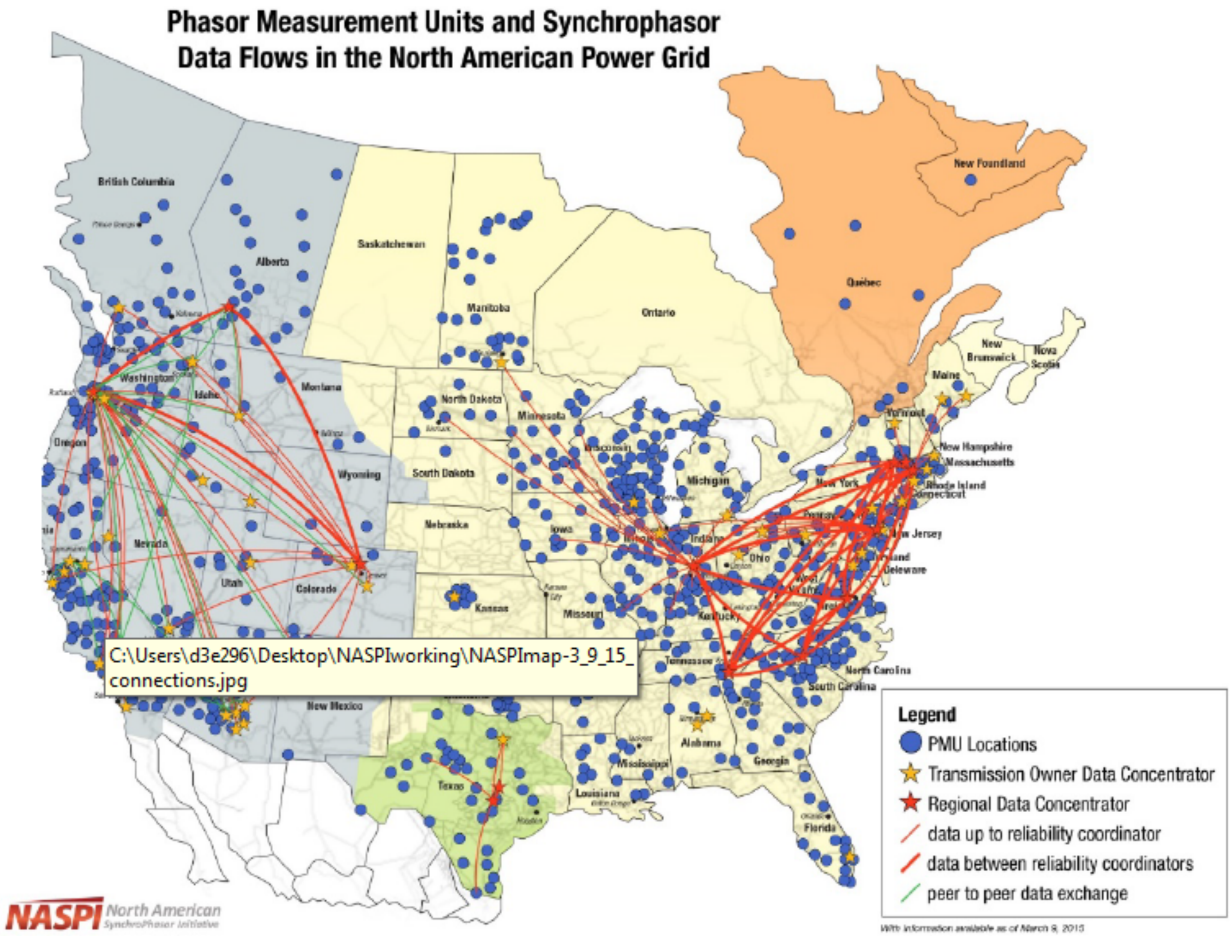
PHASOR MEASURMENT UNITS or SYNCROPHASORS

WISP – Western Interconnection Synchrophasor Program



PHASOR MEASURMENT UNITS or SYNCROPHASORS

March 2015



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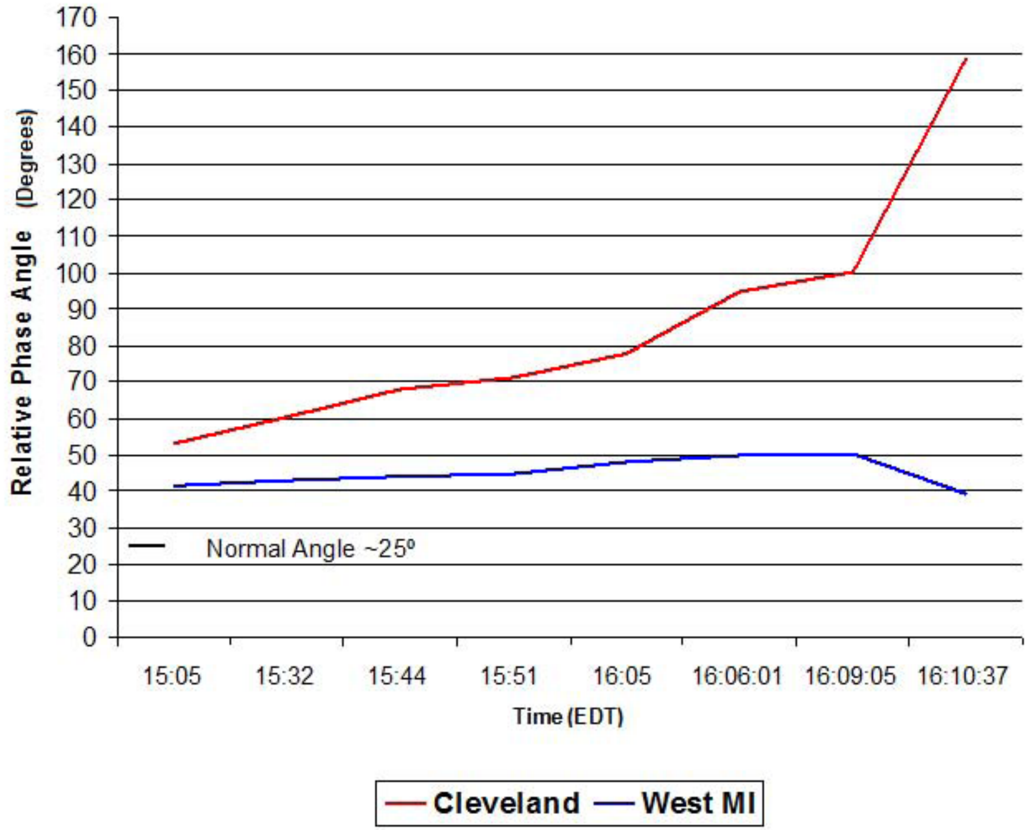
POWER SYSTEM TIMING REQUIRMENTS

Why PMUs

- High speed, real time data stream
  - 60 samples per second
- Time synchronized measurements
  - Wide area phase angle differences
- Flexibility in data stream
  - Analog and digital values are included

PHASOR MEASURMENT UNITS or SYNCROPHASORS

August 2003 East Coast Blackout



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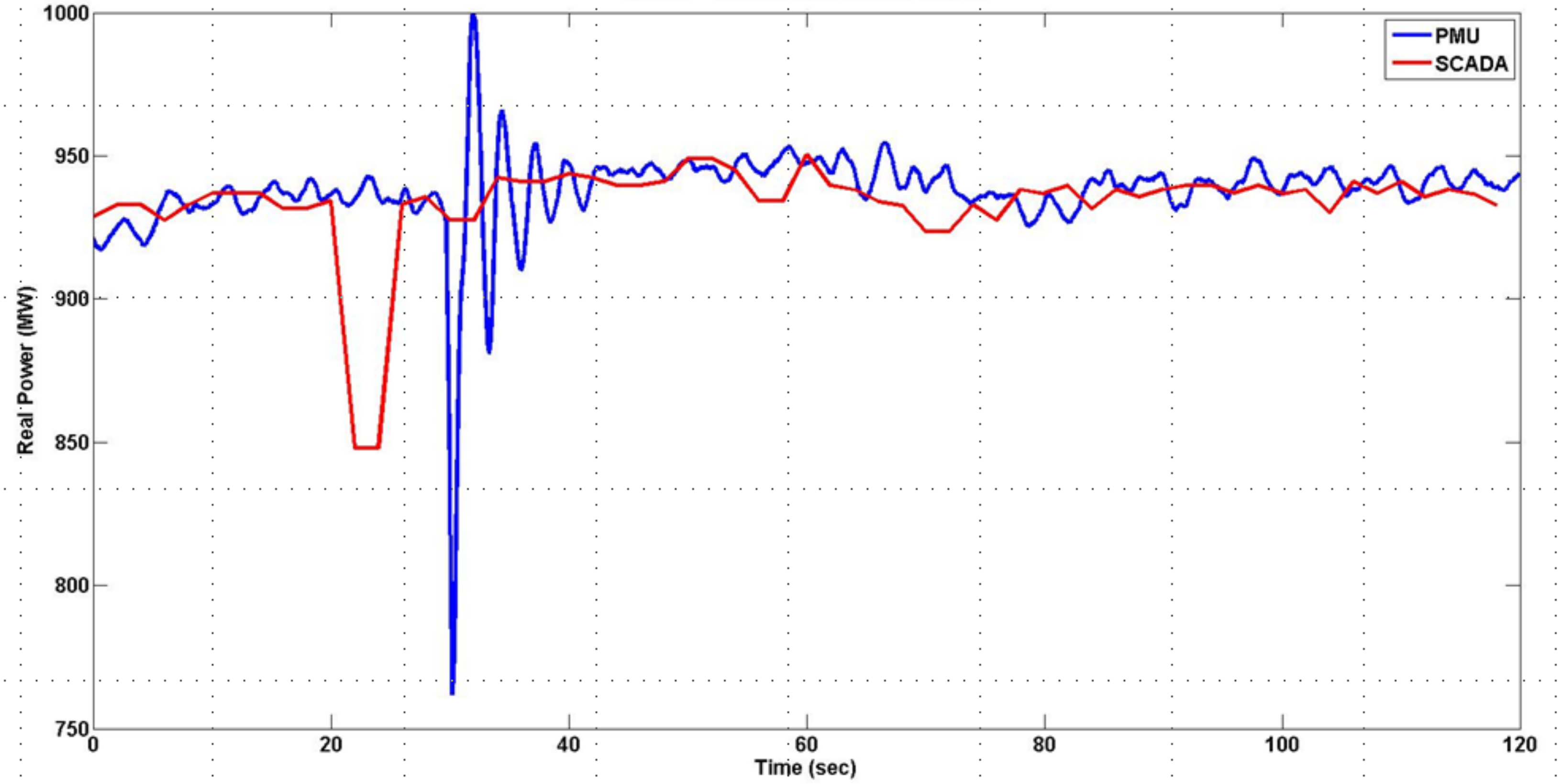
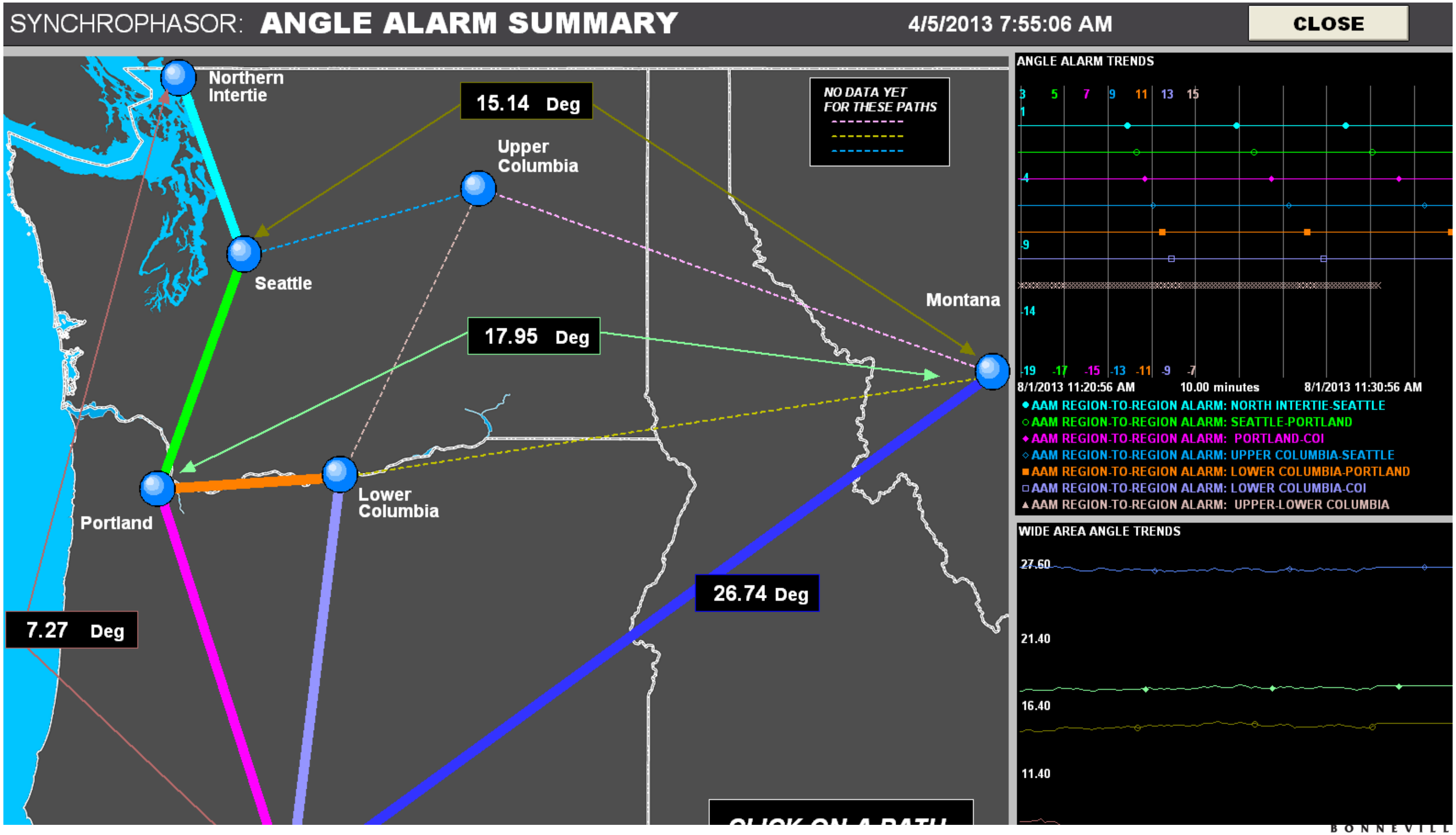
PHASOR MEASURMENT UNITS or SYNCROPHASORS

PMU vs. SCADA



Abnormal Angle



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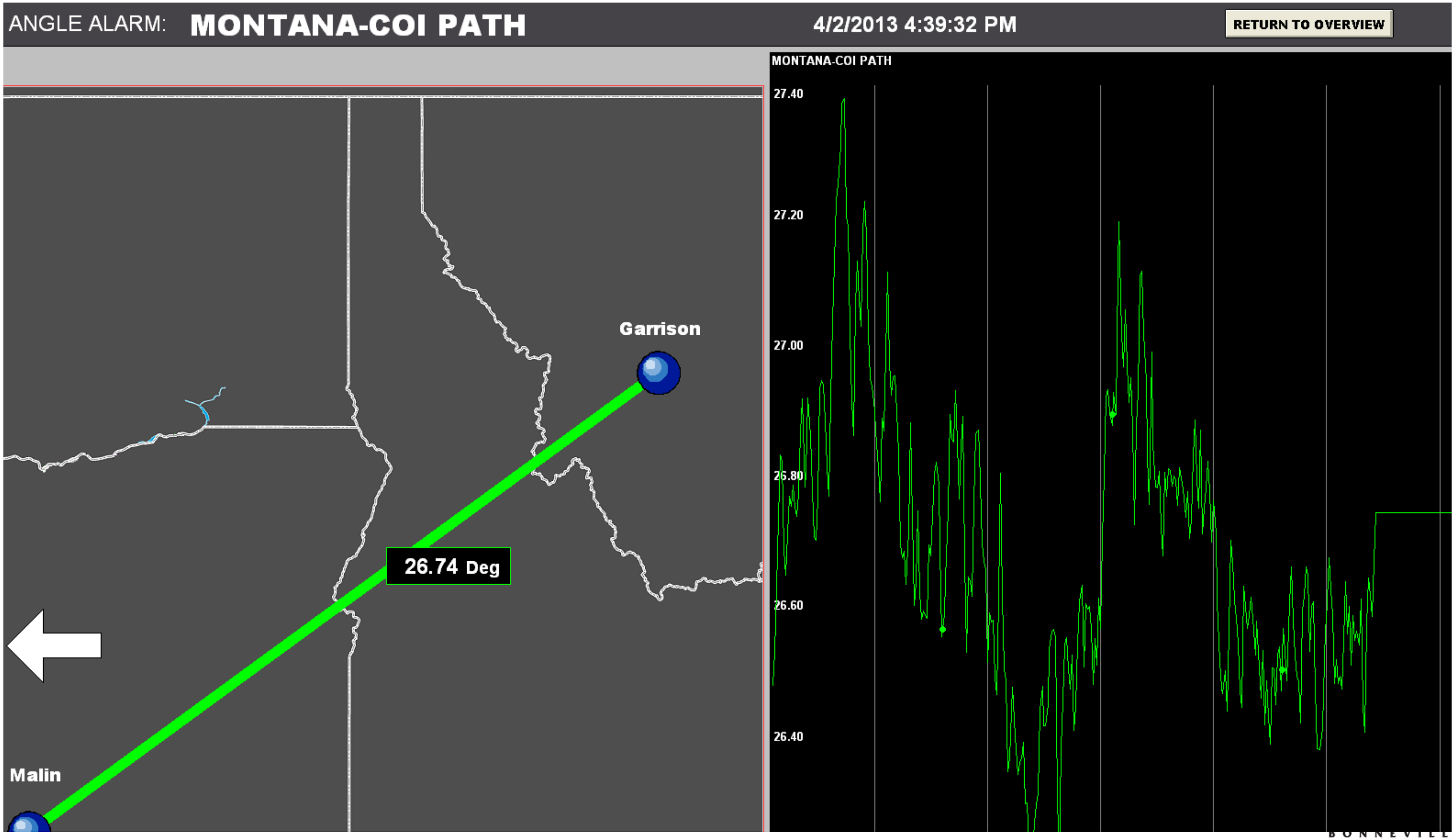
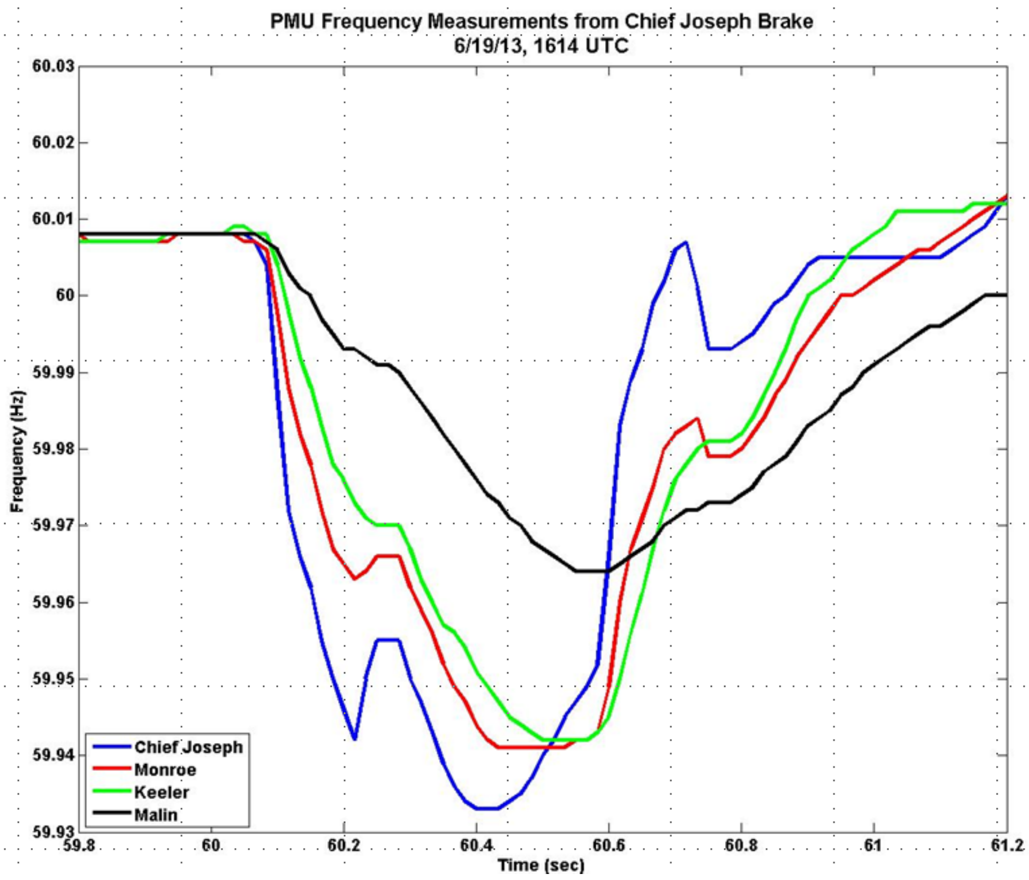
Abnormal Angle

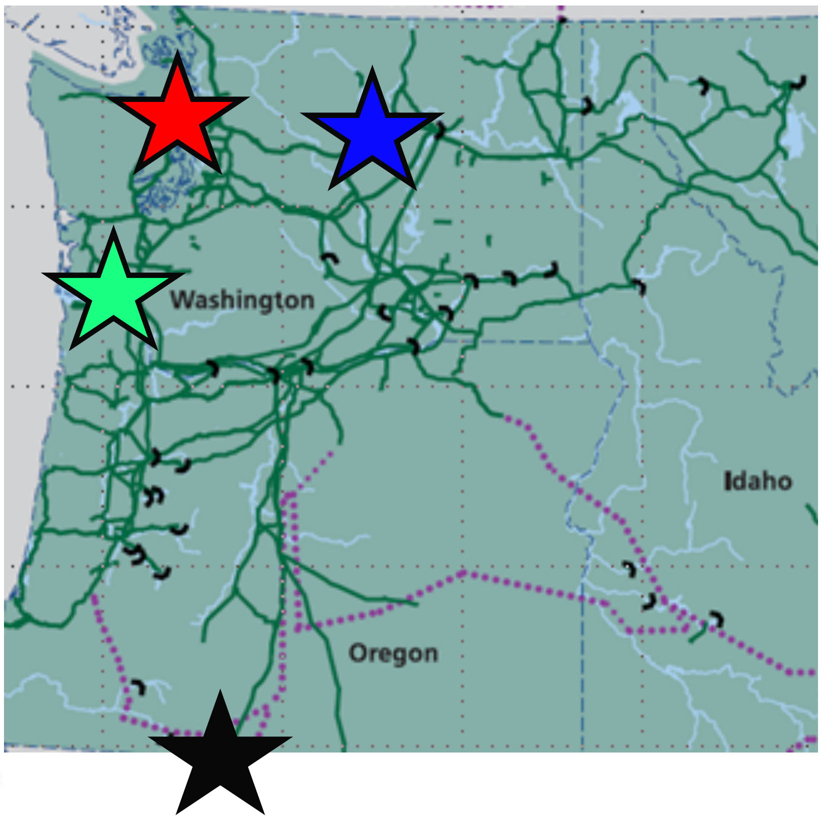


Frequency Event Location

Insertion of 1.4 Gigawatt Load Break in Eastern Washington

Frequency Event Location





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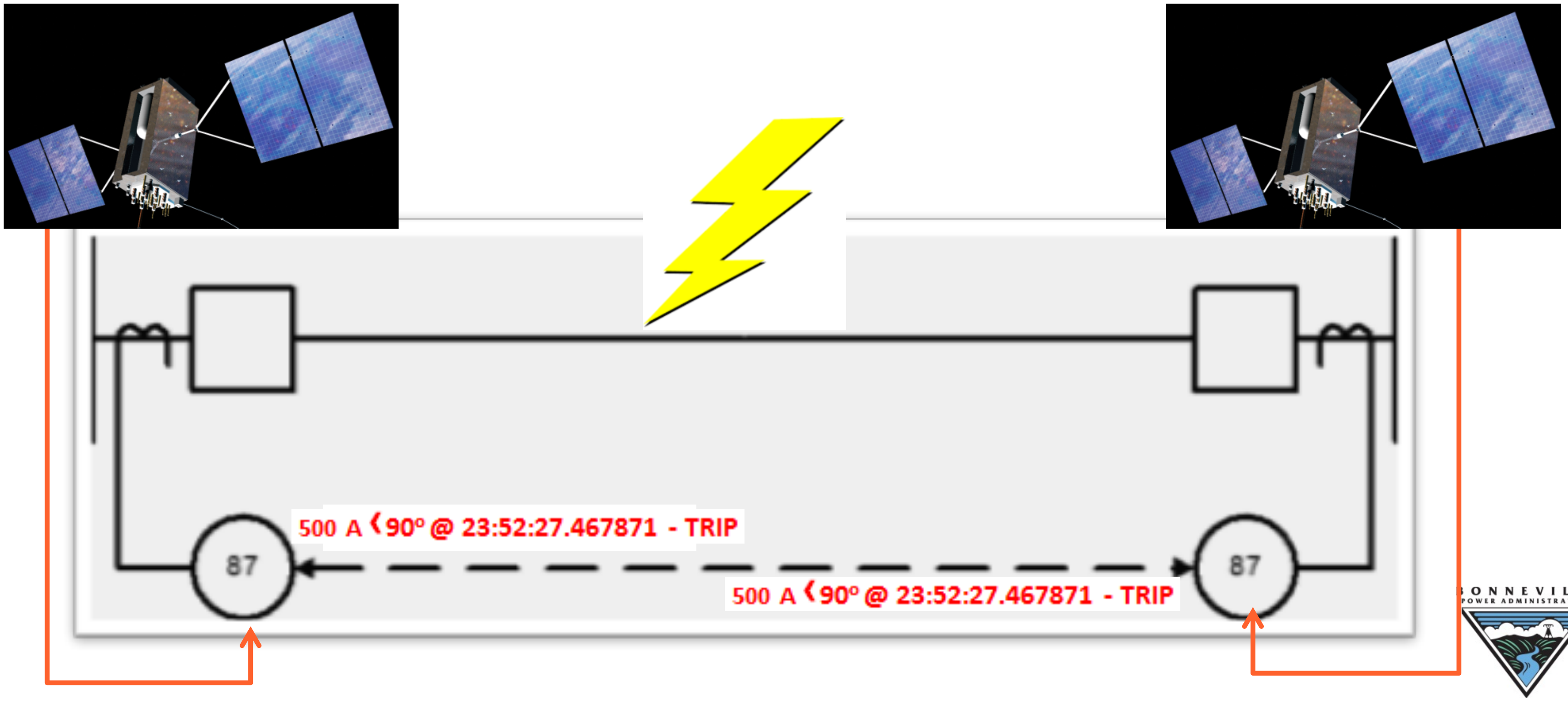
Line Differential Relays

- Compare current magnitudes, phase angles to two ends of a transmission line
- Communications and high accuracy time dependent!
- Changes in communications paths, channel delays, or timing errors can cause potential problems



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Traveling Wave Fault Location

What is a power system fault?

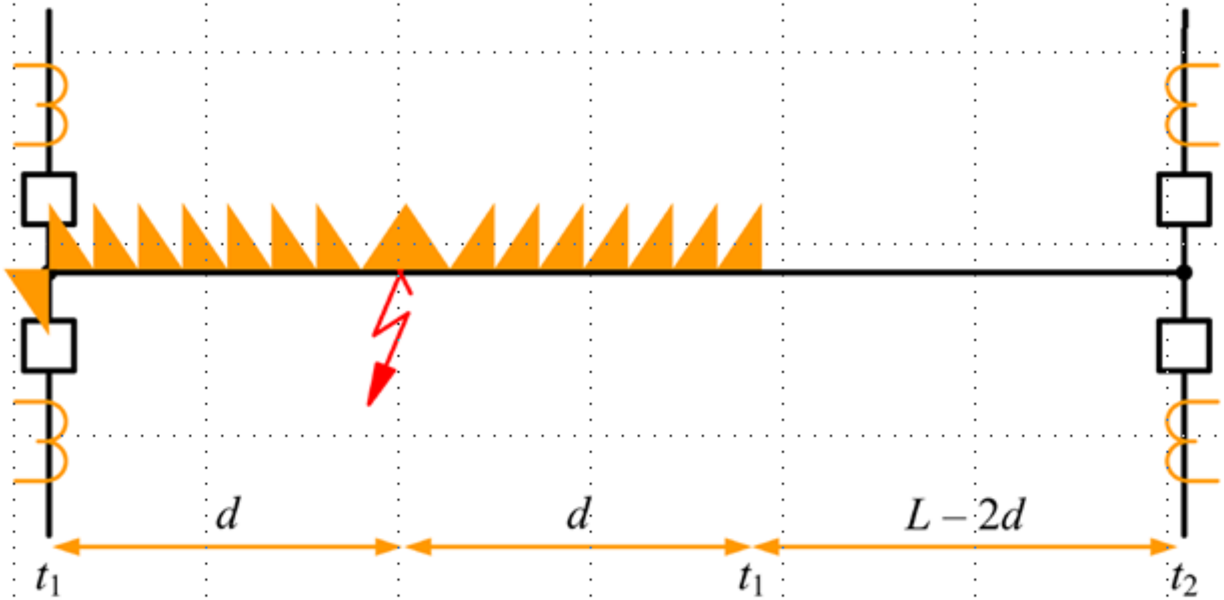
Traveling Wave Fault Location

- Drop a stone in a still pond
  - you produce a wave that moves out from the center
  - In ever increasing circles

Traveling Wave Fault Location

- Requires a sampling rate of 1.5 Mhz (500 Nano-seconds) for fault locations to be accurate within 500 feet.

Principle of Operation

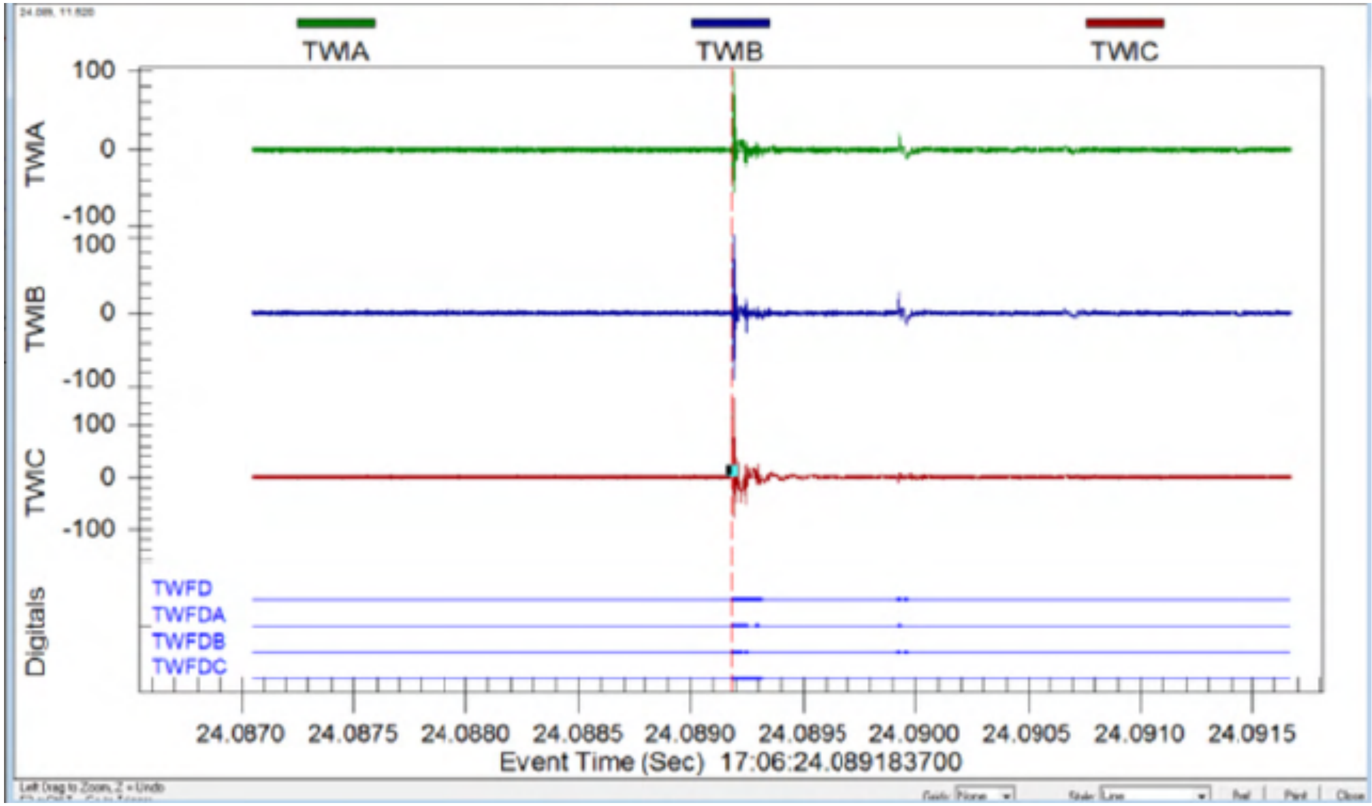


$$L-2d=v\bullet(t_2-t_1)$$

$$d=\frac{1}{2}\left(L-v\bullet(t_2-t_1)\right)$$

Traveling Wave Fault Location

- Traveling Wave Event



System Event Recording

- Digital Events requires millisecond time-tagging
  - Equipment Alarms, Power Circuit Breaker Operations

Alm	Point	Date/Time	Description	
A	369	05/16/14, 23:30:34.741	SICKLER # 1 SET # 2 RECEIVE SIGNAL FAIL	78
N	370	05/16/14, 23:33:13.347	SICKLER # 1 SET # 2 LINE DIFF DISABLED	
N	369	05/16/14, 23:33:14.047	SICKLER # 1 SET # 2 RECEIVE SIGNAL FAIL	78
A	1105	05/16/14, 23:33:14.103	5132 PCB (25E) TRIP SIGNAL SENT	
A	1081	05/16/14, 23:33:14.104	5129 PCB (22E) TRIP SIGNAL SENT	
A	368	05/16/14, 23:33:14.120	SICKLER # 1 SET # 2 RECLOSING LOCKED OUT	
A	1069	05/16/14, 23:33:14.132	5129 PCB (22E) PHASE B OPERATED	243
A	1093	05/16/14, 23:33:14.132	5132 PCB (25E) PHASE B OPERATED	250
A	1068	05/16/14, 23:33:14.133	5129 PCB (22E) PHASE A OPERATED	243
A	1092	05/16/14, 23:33:14.133	5132 PCB (25E) PHASE A OPERATED	250
A	1094	05/16/14, 23:33:14.133	5132 PCB (25E) PHASE C OPERATED	250
A	1070	05/16/14, 23:33:14.133	5129 PCB (22E) PHASE C OPERATED	243
A	359	05/16/14, 23:33:14.140	SICKLER # 1 SET # 1 RECLOSING LOCKED OUT	
A	695	05/16/14, 23:33:14.151	500 KV TRIPPED BY RELAY ACTION	ALM1
A	350	05/16/14, 23:33:14.164	SICKLER LINE 1 SET 1 HOT LINE INDICATION	32
A	22	05/16/14, 23:33:14.167	DIGITAL FAULT RECORDER OPERATE	ALM3
N	368	05/16/14, 23:33:14.607	SICKLER # 1 SET # 2 RECLOSING LOCKED OUT	
N	1081	05/16/14, 23:33:14.613	5129 PCB (22E) TRIP SIGNAL SENT	
N	1105	05/16/14, 23:33:14.614	5132 PCB (25E) TRIP SIGNAL SENT	

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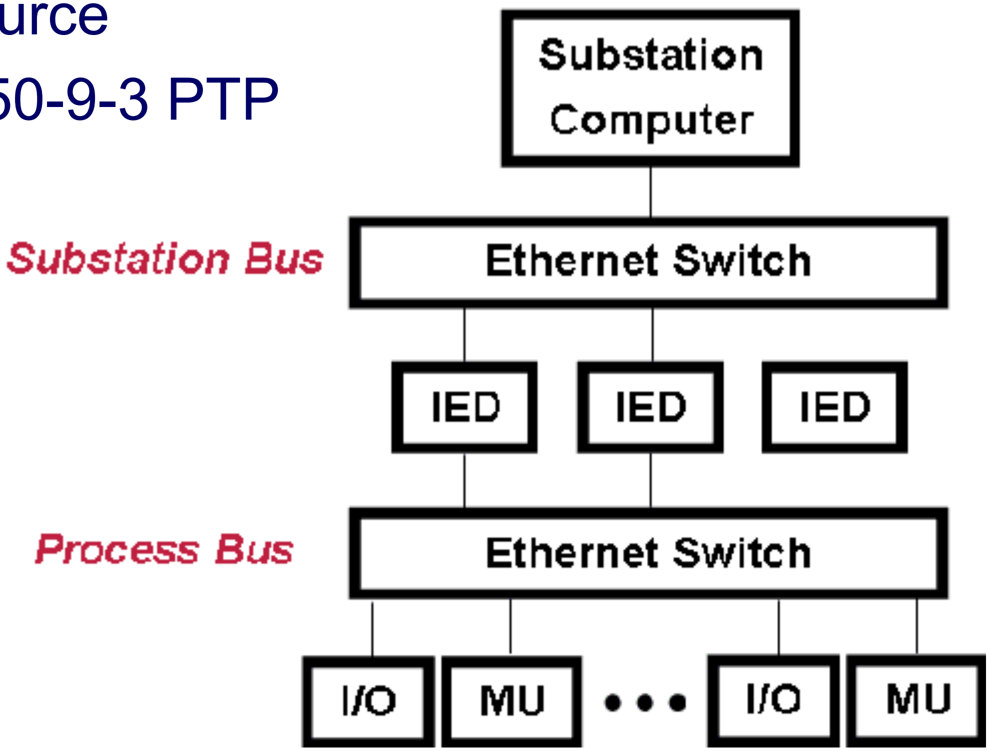
Substation Local Area Networks

- IEC – 61850 GOOSE Messages – 1ms accuracy
  - SNTP – 1ms accuracy
- IEC – 61850 Sample Values - 1 micro second accuracy
  - 1PPS Sync Source
  - C37.238 / 61850-9-3 PTP



Power System disturbances caused by un-synchronized time

- 500kV transmission line outage caused by Bad GNSS data
  - Line current differential during GPS testing
- Investigation revealed Airforce GPS satellite testing
- Some GPS receivers were affected
- Official Notice: Since March 15, 2014, the Air Force has been conducting functional checkout on a GPS satellite, designated Space Vehicle Number (SVN) 64. SVN 64 broadcasts a data message that clearly indicates SVN 64 is unusable for navigation. http://www.gps.gov/news/2014/05/GPS-device-problem/

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Power System disturbances caused by un-synchronized time

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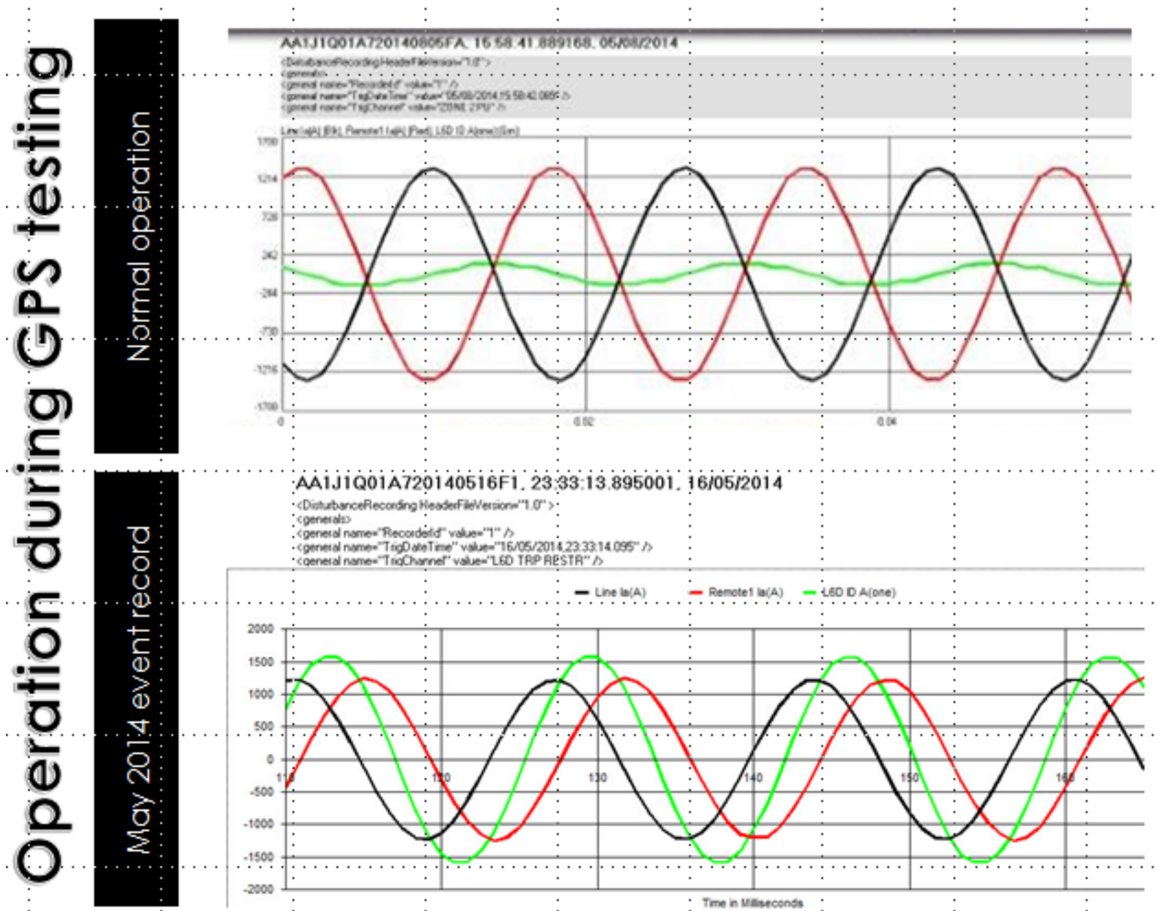

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Power System Disturbances Caused by Un-Synchronized Time

- Resolutions and joint learning
  - Track planned GPS testing notices
  - Use GPS receivers that detect test mode
  - Use in-channel timing as source/backup
  - Desensitized differential phase preferably above load and below internal fault
  - Utilize zero and negative sequence differential elements

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Power System Disturbances Caused by Un-Synchronized Time

FEDERAL AVIATION ADMINISTRATION

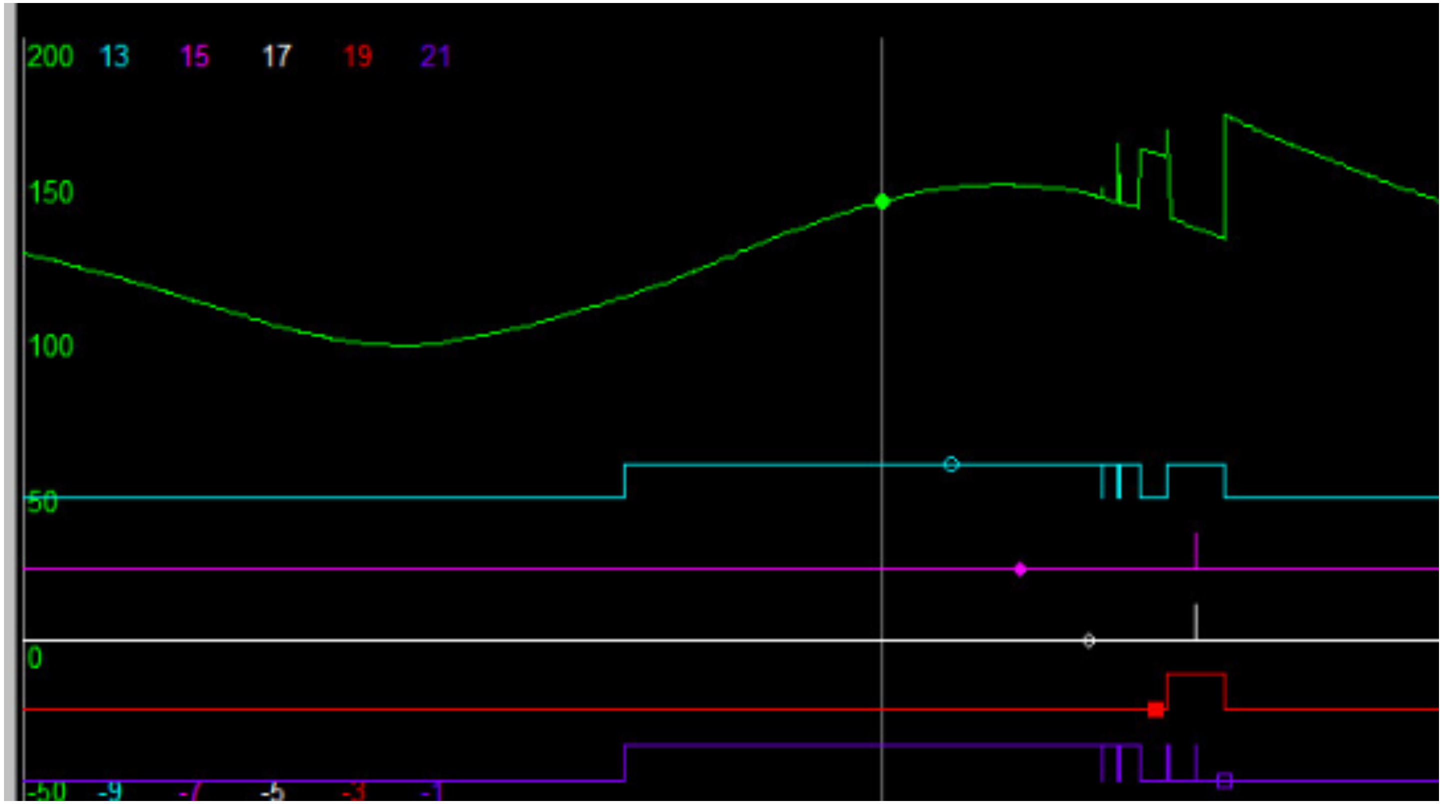
FLIGHT ADVISORY
GPS Interference Testing
CHLK GPS 16-08
07-30 June, 2016
China Lake, California

GPS testing is scheduled as follows and may result in unreliable or unavailable GPS signal.

Example of PMU bad data caused by un-synchronized time

- Several PMU lost GPS Sync on 3/15 for several minutes
- During the event, there were multiple instances of both PMUs reporting that the synch had been re-established and that their status was good - even though it wasn't.
- Redundant PMU did not experience this problem.
- We are confident that the synch was not re-established because the phase angle for these PMUs jumped by 40 degrees each time the status cleared.

Example of PMU bad data caused by un-synchronized time



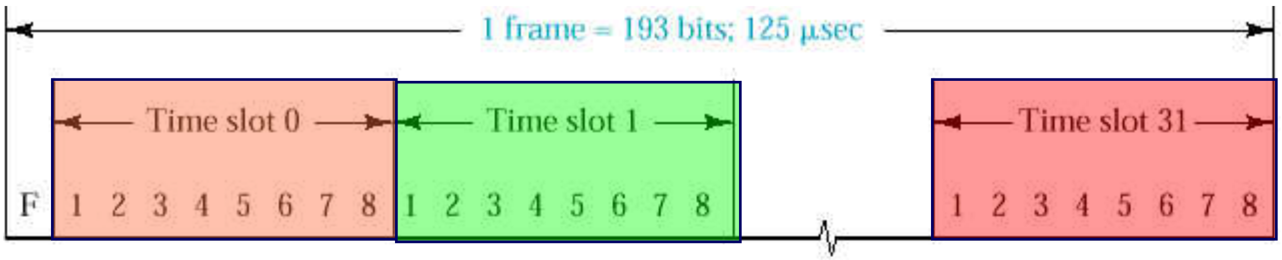
Synchronization Accuracy monitoring relies on system data.

BPA Communications

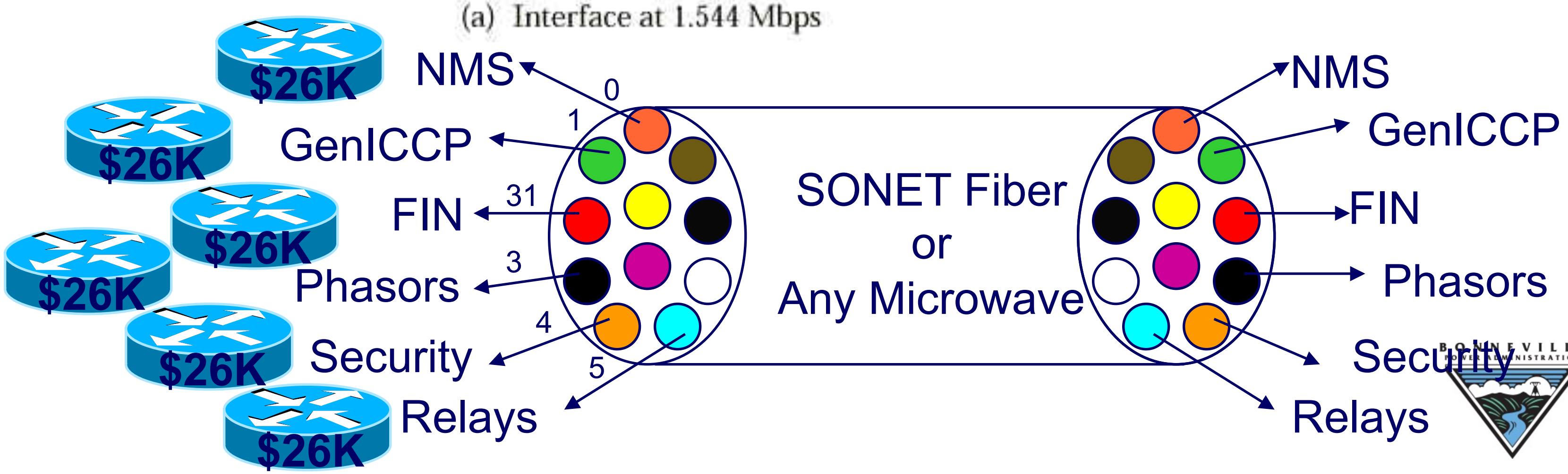
- BPA covers 4 states with thousands of command and control circuits on legacy systems.
- The legacy communications systems are going EOL
- Maintenance is also becoming an issue

What do we have?

The BPA communication system consists of Microwave (MW) and Synchronous Optical Networking (SONET) over Fiber Optics (FO). All of these communications systems utilize Time Division Multiplexing (TDM) technology to share the total bandwidth. <u>Though functional, this implementation is inefficient and costly when supporting IP networks.</u>



(a) Interface at 1.544 Mbps



What do we need?

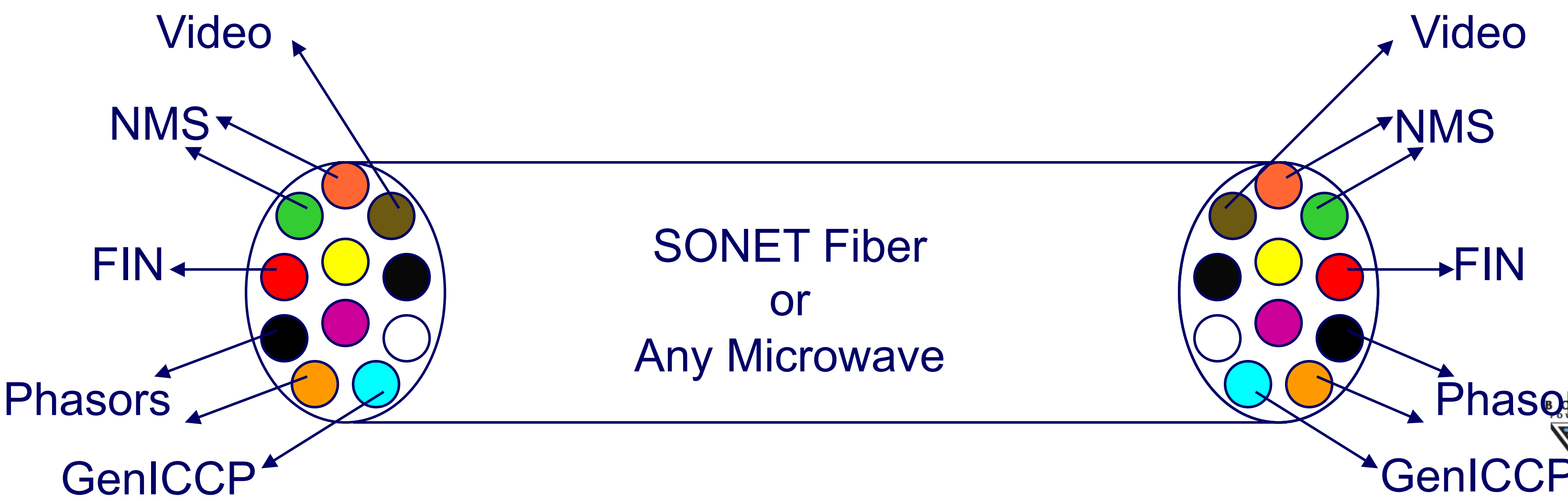
We need a system with the reliability of SONET but the ability to make use of idle bandwidth for other applications. We need traffic to travel across the transport at the maximum speed the physical medium supports, to allow new applications of technology. We need a system requiring less overall impact.

Video conferencing needs 384 kbps.
Assume 4 hours use per day = 5.5 Gbit.
20 hours of idle time = 27.5 Gbit.

80% of the bandwidth is wasted daily!

100 byte travel time

DS-0	**12.5ms**
T-1	**0.5ms**
Gigabit	0.0008ms



Carrier Ethernet – PBB-TE

Provider Backbone Bridge Traffic Engineering

- After exhaustive evaluation we chose Carrier Ethernet as our next Transport Infrastructure
- PBB-TE supports SONET like switch times with some notable constraints. 16/1200
- PBB-TE deterministic, connection oriented services
- Carrier Grade reliability and availability

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What Protection Engineers Need to be asking

- Latency Requirements for Services requested
- Asymmetry (Packet Jitter) specification
- How does switch time spec affect function
- What connections are going to be provided – physical fiber connector types
- Blocking mechanisms a sufficiency on links that can appear active with as much as 20% packet loss

Conclusion

- Background on BPA Power System
- Precise Timing Applications
- Events that show how sync affect protection were discussed
- Power Systems cover large areas requiring accurate timing to keep the system balanced.
- Evolution of com system is coming
  - Along with it are the timing requirements

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Questions?

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