SALT RIVER PROJECT - SYNCHROPHASOR TEAM

Lessons Learned Integrating Synchrophasors into EMS Applications

NASPI Working Group Meeting
Scottsdale, AZ
February 04, 2009

Dr. Naim Logic
Bill Robertson

Outline of presentation

- Synchronized Phasor Measurements
  - Synchrophasor Team “Lab”
- Visualization Tools
  - From StreamReader (BPA) … to RTDMS (EPG)
- R & D Projects
  - SRP / ASU Joint Research Program
- OpenPMU
  - PDC configuration
  - Data validation
  - Cyber security issues and ESP
  - SE utilization: software changes and tuning efforts

SRP Synchrophasor Team

- An ongoing, multidepartmental effort
  - Computer Applications
  - Communications Engineering
  - Communications C&M
  - Transmission Planning
  - System Protection
  - System Operations
  - Control Engineering
  - Relay Shop

Team Accomplishments

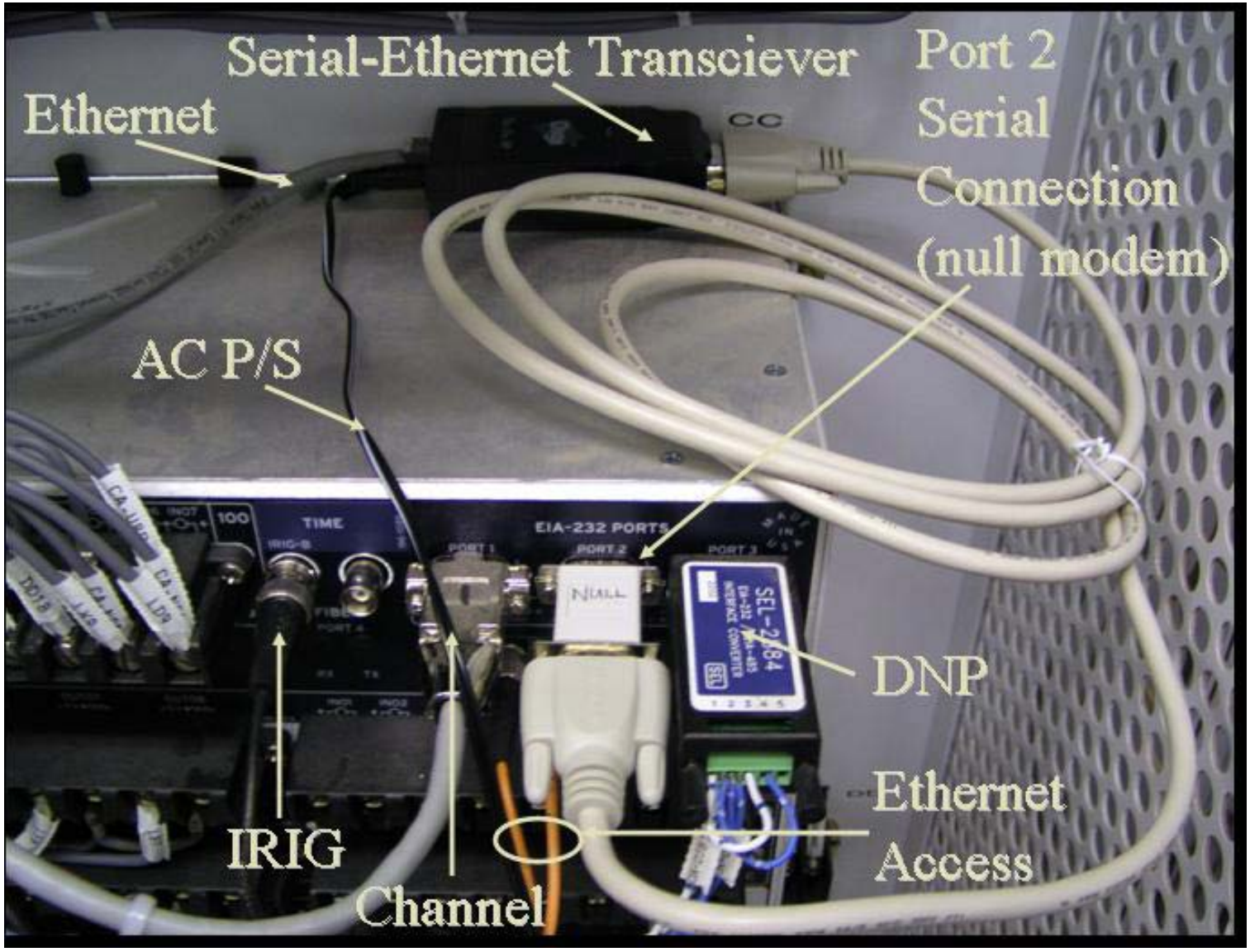
- Utilized PMU data during Black Start exercises
- Installed permanent PMUs for Black Start
- Installed permanent PDC network
- Initiated EIPP/NASPI involvement
- Evaluated GE N60 & L90 PMU capabilities
- Activated SEL-421 as PMUs
- Funding research with ASU
- Published technical papers

Relay-based PMUs

- It is a growing trend:
  - SEL-421s
  - SEL-3xx series
  - GE N60s
  - GE L90s

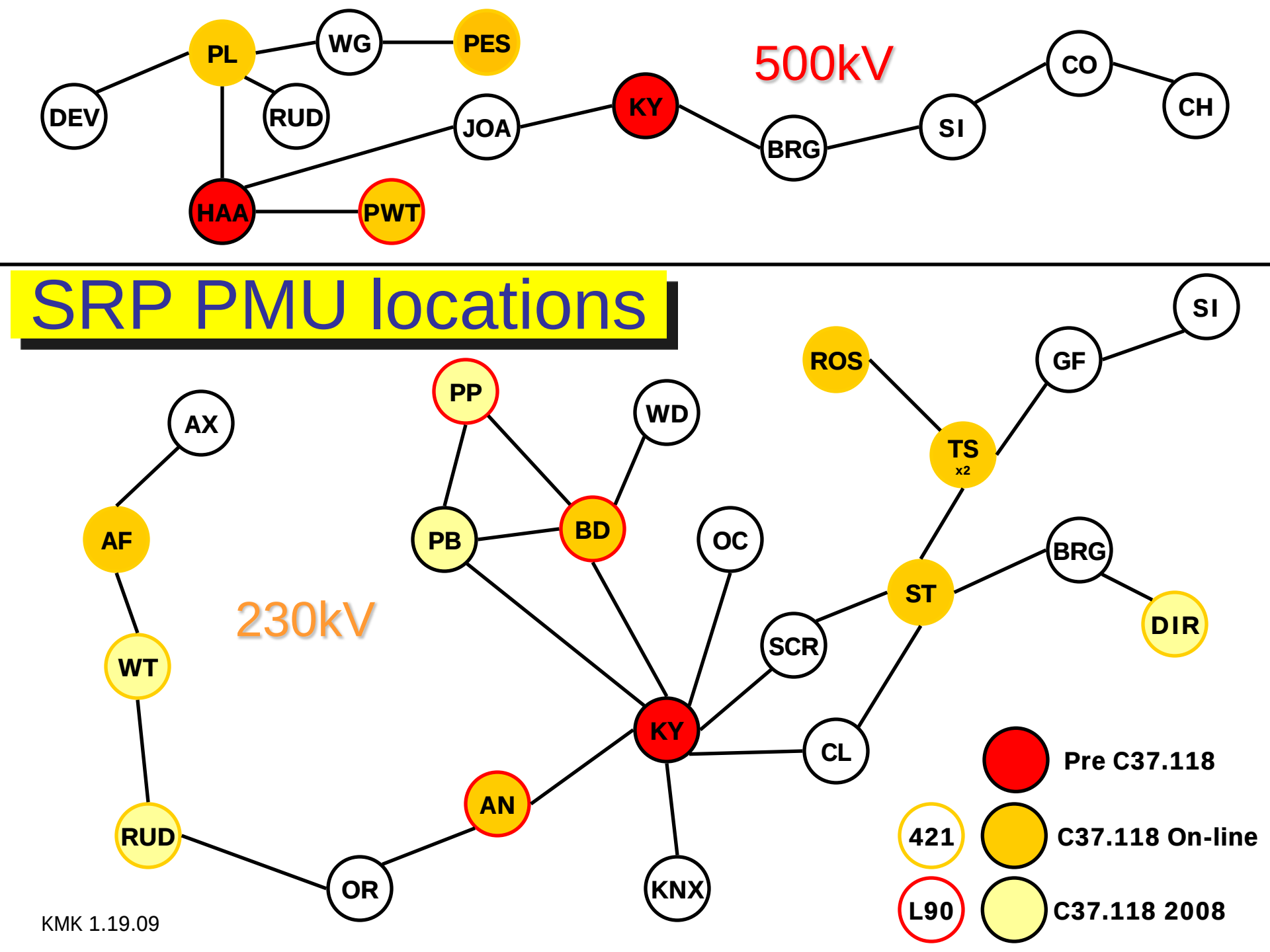
- It is becoming a standard option

SEL-421 PMU connection

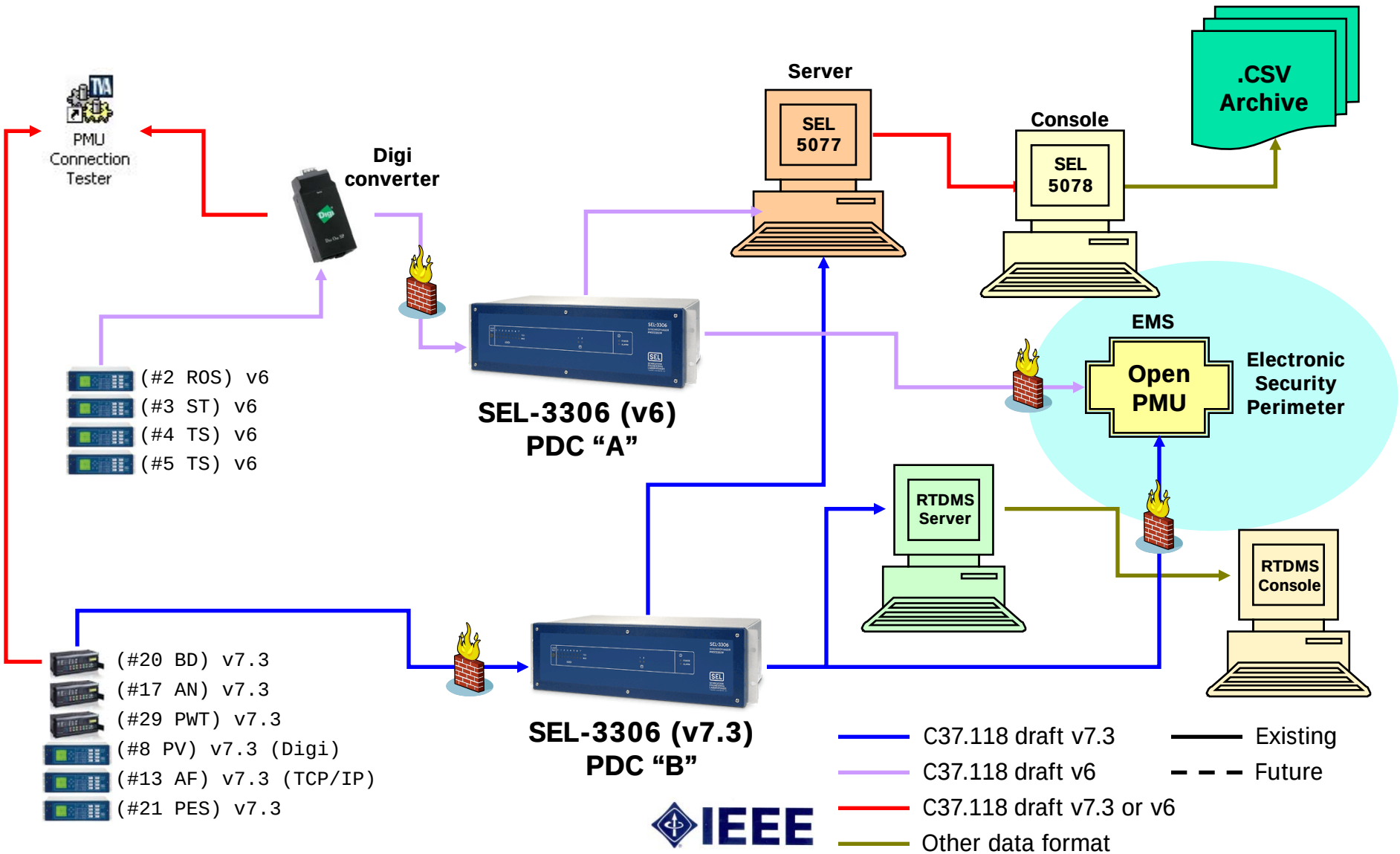


Relay-based PMUs

Relay	Availability	Cost	Quality	Suitability
SEL-421	Now	$270 per upgrade, incl. w/new relay	Meets IEEE C37.118 std, tested by SRP	Found on many SRP 230/500kV lines
GE N60	Now	~$4K per upgrade, cost w/new relay	Meets IEEE C37.118 std, tested by SRP	Found on PV-COI RAS scheme, but no CT/PT inputs
SEL-3xx series	Now	$270 per upgrade, incl. w/new relay	Does not meet IEEE C37.118 std, not yet tested	Found at SRP's 115kV level and below
GE L90, D60	Now	~$4K per upgrade, cost w/new relay	Meets IEEE C37.118 std, L90s tested	Found on many SRP EHV lines as well as 69kV (L90)


500kV
PL
WG
PES
DEV
RUD
JOA
KY
BRG
SI
CO
CH
HAA
PWT
SRP PMU locations
230kV
AX
AF
WT
RUD
OR
PP
WD
PB
BD
OC
AN
KY
KNX
ROS
GF
SI
TS
x2
ST
BRG
DIR
SCR
CL
Pre C37.118
421
C37.118 On-line
L90
C37.118 2008
KMK 1.19.09

Synchrophasor Team “Lab”



KMK 1.20.09

SEL-3306 PDC Output Detail

SEL-3306 (v6)
PDC “A”

- OUTPUT1 – 30/sec – SynchroWAVe Server
- OUTPUT2 – ##/sec – Spare
- OUTPUT3 – 1/sec – OpenPMU DAC1
- OUTPUT4 – 1/sec – OpenPMU DAC2

SEL-3306 (v7.3)
PDC “B”

- OUTPUT1 – 30/sec – SynchroWAVe Server
- OUTPUT2 – 30/sec – RTDMS Server
- OUTPUT3 – 1/sec – OpenPMU DAC1
- OUTPUT4 – 1/sec – OpenPMU DAC2

KMK 12.17.08

Visualization Tools

- StreamReader (BPA)
  - LabView based – Ken Martin
- DSI - Dynamic System Identification Toolbox (PNL)
  - MATLAB based – John Hauer, Henry Huang
- PSO – Power System Outlook (SCE)
  - Windows based – Armando Salazar
- RTDMS – Real-Time Dynamic Monitoring System
  - Electric Power Group – Manu Parashar

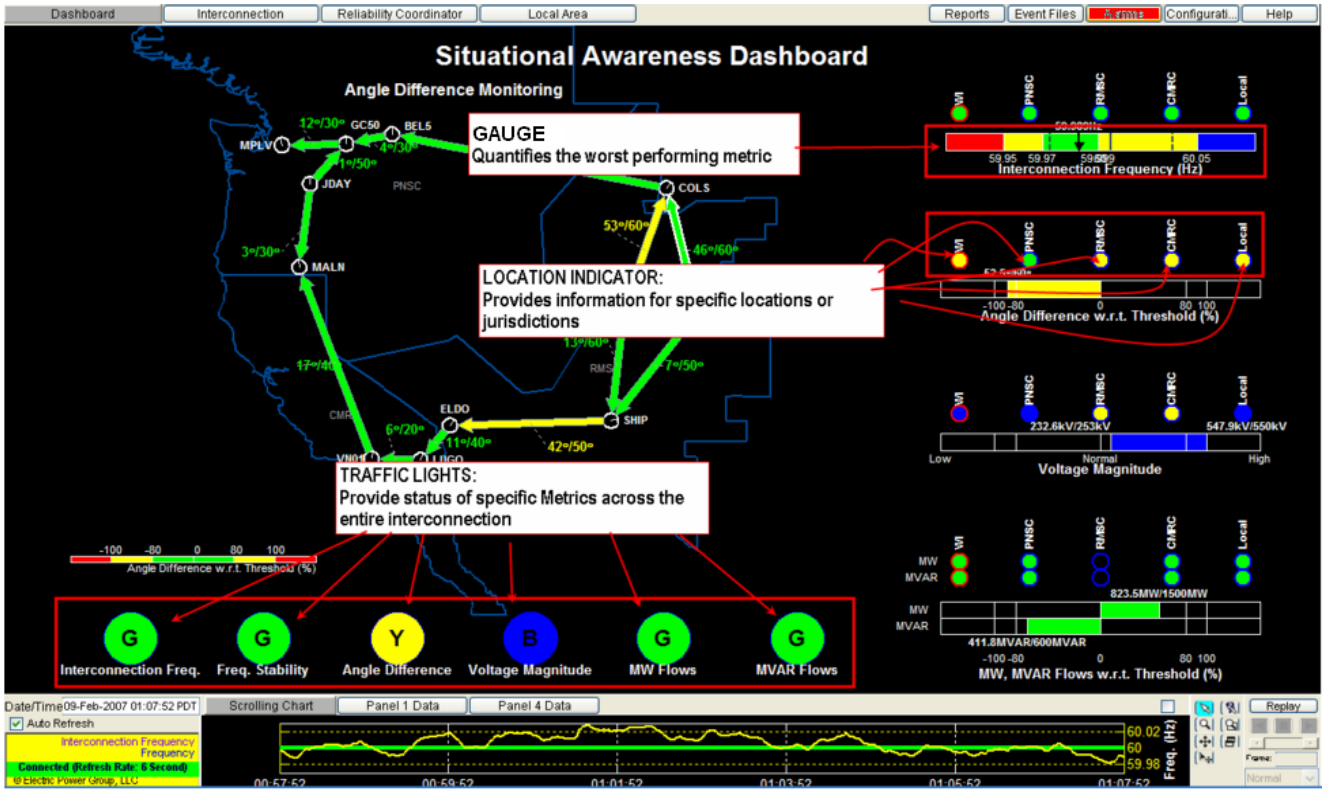
Industry Software Packages

- SynchroWAVe (SEL)
  - SEL-5077 – Server software
  - SEL-5078 – Console software
- FNet – Frequency Network (VA Tech)
  - FDR – Frequency Disturbance Recorder – Prof. Liu
- ePDC – Enhanced Phasor Data Concentrator (EPG)
  - Beta testing site ? – Ken Martin, Manu Parashar
- OpenPMU (OSI) – Ongoing project
  - The challenge is to develop a functioning SE with synchronized phasor measurements when the system is not yet observable by PMUs

Visualization Tools

RTDMS

- **Working on:**
  - Data configuration
  - Developing concepts for RTDMS displays
  - Placement of client data displays



SRP/ASU Joint Research Program

- Optimal PMU positioning in Electric power system – based on achieving maximum SE improvement (Prof. Heydt, Vittal) - **completed**
- Synchrophasor technology in validation of T-line impedance parameters (Prof. Tylavsky) – **in progress**
- Decision tree assisted online Security Assessment using PMU measurements (Prof. Vittal) – **in progress**
- Generator dynamic parameters validation (Prof. Heydt) – **working on proposal**

Observations

- PMU – most important measuring device in the future of power system monitoring and control
- We anticipate a gradual migration towards full PMU implementation for power system
- PMU can / will revolutionize the way power systems are monitored and controlled
- A system of PMUs must be supported by communication infrastructure of sufficient speed to match the fast streaming PMU measurements
  - WECC Synchronized Phasor Network (DMWG & WAMTF)
  - NASPInet

Team Future Efforts

- Expansion plan is underway
  - CO-SI, KY-JOA, Rudd, …
- OpenPMU - EMS integration
- Pursuing visualization packages (RTDMS)
- Evaluating Arbiter 1133A as PMU device
- Hathaway DFR upgrades
- WECC DMWG & WAMS Task Force involvement
- Becoming foundation for SRP Smart Grid vision
  - PMU Network at Transmission level
  - AMI at Distribution level

PMU Data within the EMS

- New software - OpenPMU
- Data sources: PMUs and PDCs
- Configuration issues
  - PMU / PDC
  - Network / Firewall
  - OpenPMU
  - State Estimator

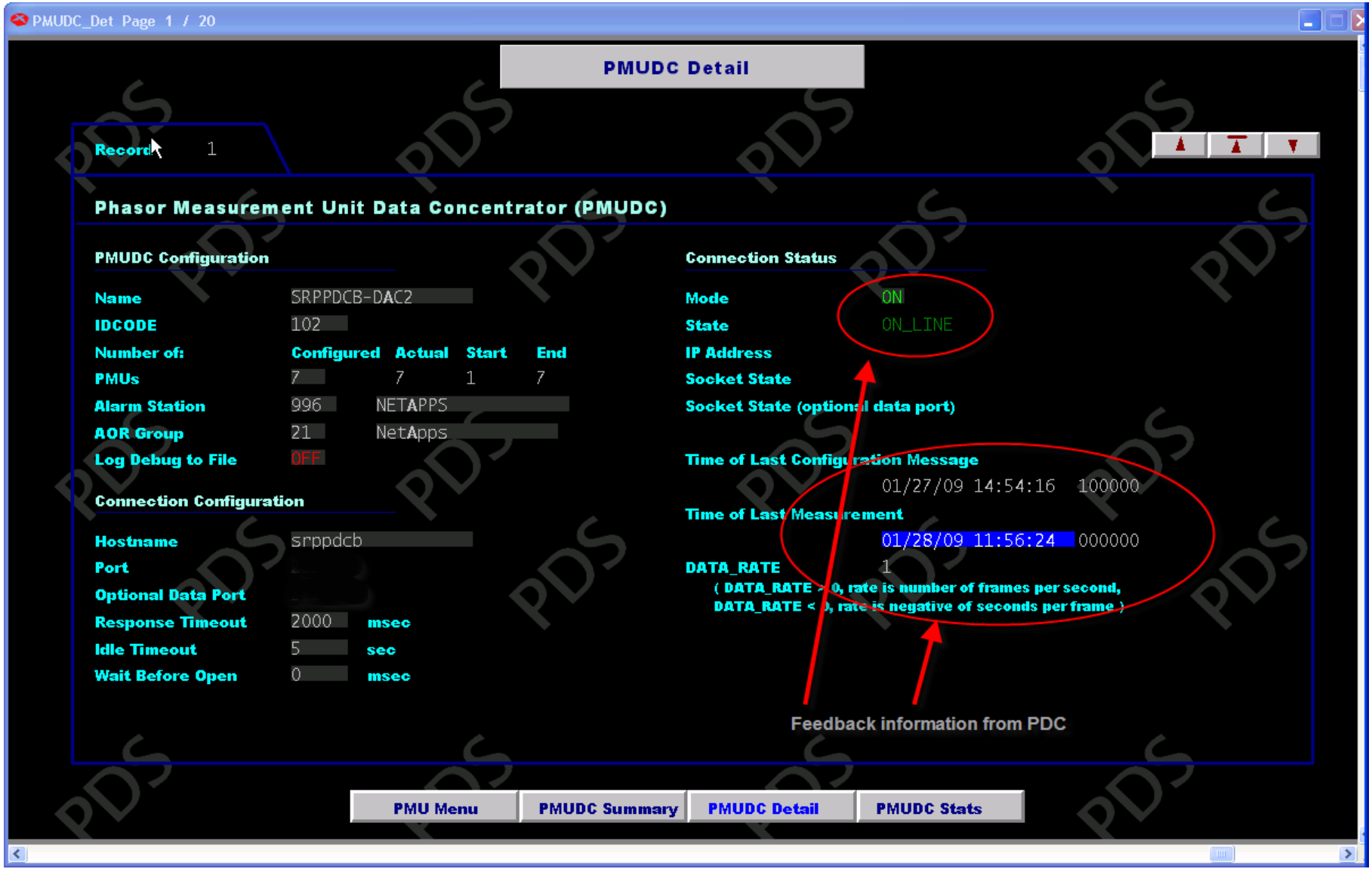
OpenPMU

- Installation of 3 components:
  1. New OpenPMU software
  2. Enhance Network Applications (SE)
  3. Patch for FEP (Front End Processor)

OpenPMU - Setup

- Initial installation did not work
- Where to start troubleshooting?
  - PMU / PDC data stream configuration?
  - Firewall configuration?
  - EMS Software?

OpenPMU

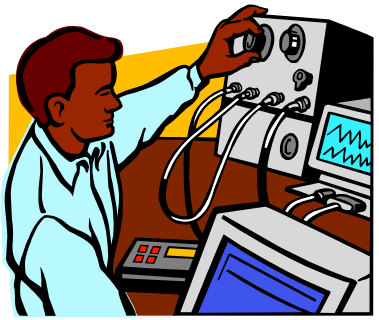

PMUDC_Det Page 1 / 20
PMUDC Detail
Record 1
Phasor Measurement Unit Data Concentrator (PMUDC)
PMUDC Configuration
Name SRPPDCB-DAC2
IDCODE 102
Number of: Configured Actual Start End
PMUs 7 7 1 7
Alarm Station 996 NETAPPS
AOR Group 21 NetApps
Log Debug to File OFF
Connection Configuration
Hostname srppdcb
Port
Optional Data Port
Response Timeout 2000 msec
Idle Timeout 5 sec
Wait Before Open 0 msec
Connection Status
Mode ON
State ON_LINE
IP Address
Socket State
Socket State (optional data port)
Time of Last Configuration Message
01/27/09 14:54:16 100000
Time of Last Measurement
01/28/09 11:56:24 000000
DATA_RATE 1
(DATA_RATE > 0, rate is number of frames per second,
DATA_RATE < 0, rate is negative of seconds per frame)
Feedback information from PDC
PMU Menu
PMUDC Summary
PMUDC Detail
PMUDC Stats

OpenPMU Troubleshooting

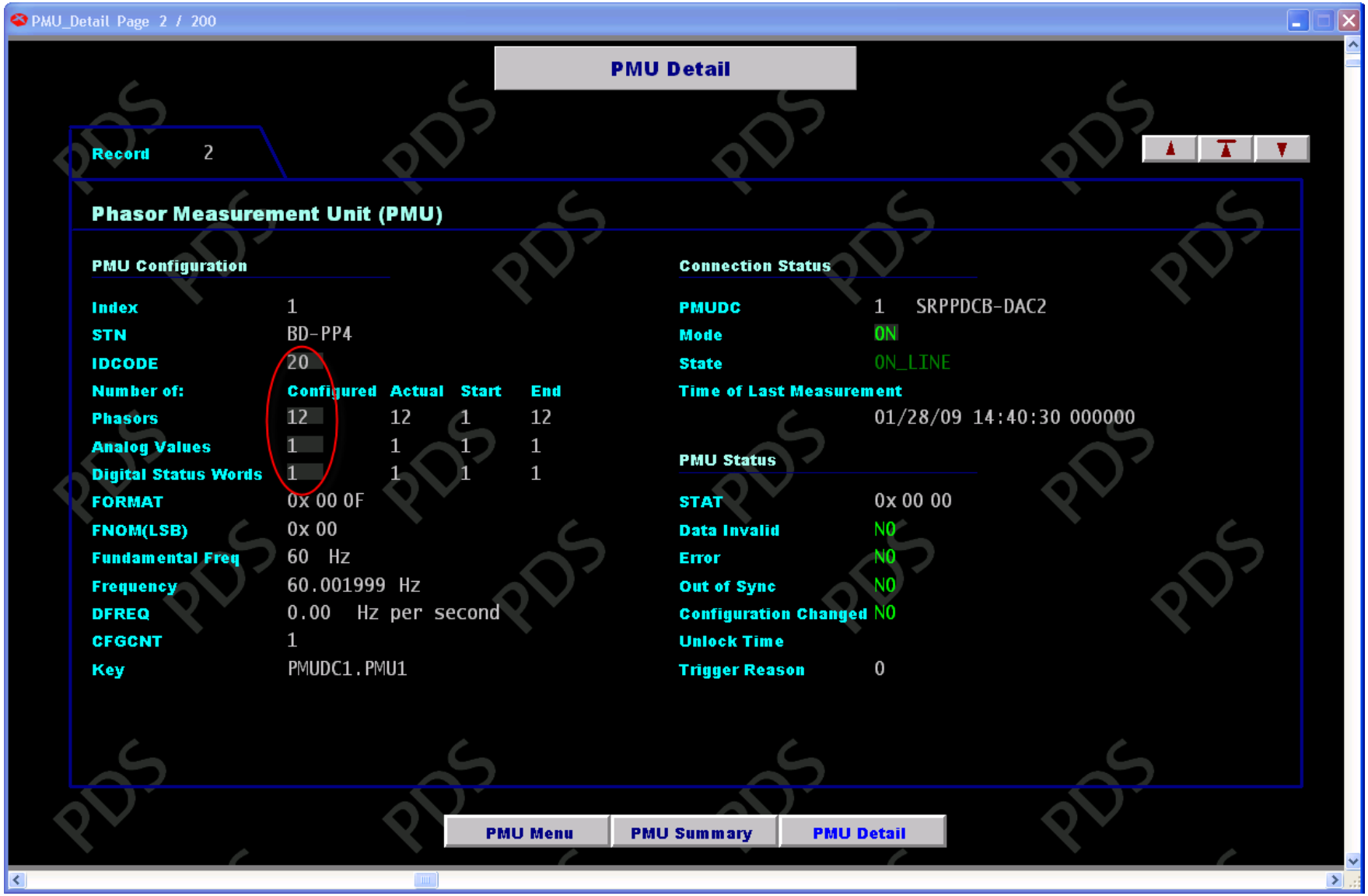
- Start over using known software, but now in the EMS domain
- Chose RTDMS server
- Configure PDC to stream data to RTDMS
- Configure firewalls to allow data stream
- RTDMS worked!

OpenPMU Rev 2

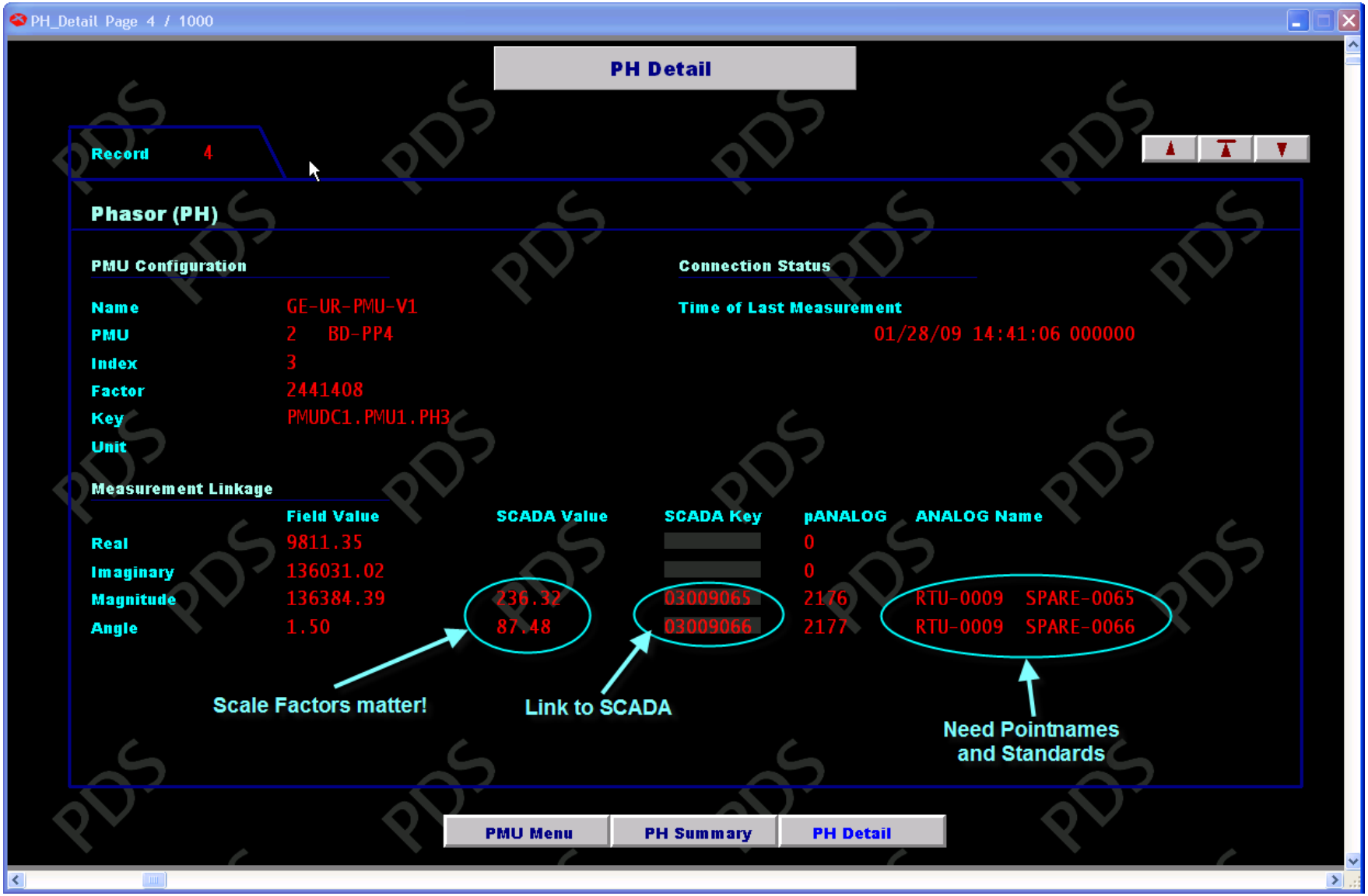
- New version of OpenPMU installed
- Confirmed firewall and PDC configurations
- OpenPMU now receiving PMU data
  - From PDC “B”
- Configure OpenPMU to understand PMU data



PMU Configuration

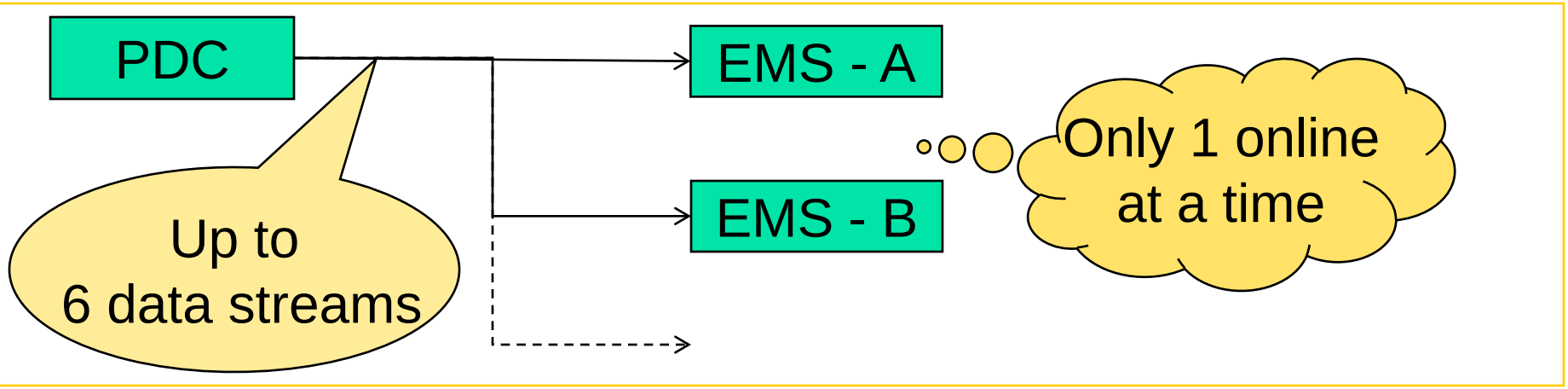


Phasor Configuration

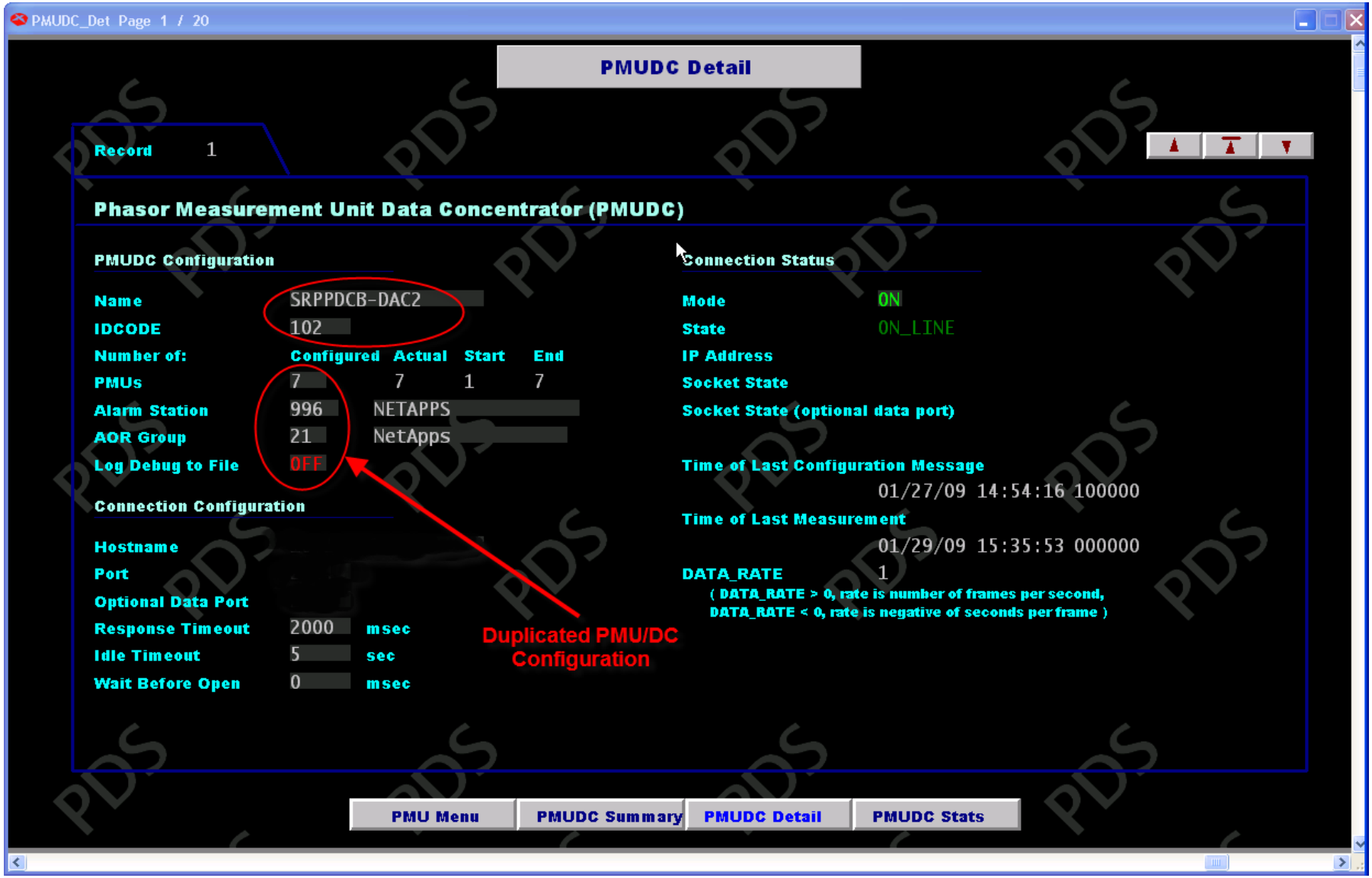


PDC vs the EMS

- PDC's are configured for output to a single IP address and port
- EMS has two (maybe more) potential listeners
- Enhancements needed in OpenPMU software
- Configured individual PDC streams for each EMS host in order to continue testing



OpenPMU


PMUDC_Det Page 1 / 20
PMUDC Detail
Record 1
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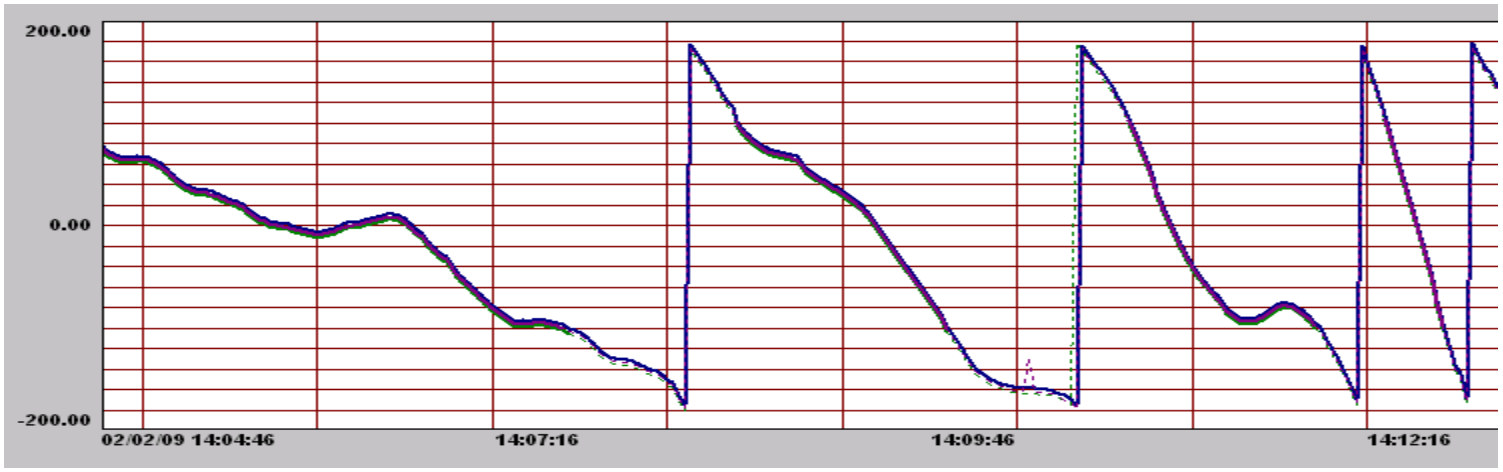
PMUDC Configuration
Name SRPPDCB-DAC2
IDCODE 102
Number of: Configured Actual Start End
PMUs 7 7 1 7
Alarm Station 996 NETAPPS
AOR Group 21 NetApps
Log Debug to File OFF
Connection Configuration
Hostname
Port
Optional Data Port
Response Timeout 2000 msec
Idle Timeout 5 sec
Wait Before Open 0 msec
Connection Status
Mode ON
State ON_LINE
IP Address
Socket State
Socket State (optional data port)
Time of Last Configuration Message
01/27/09 14:54:16 100000
Time of Last Measurement
01/29/09 15:35:53 000000
DATA_RATE 1
(DATA_RATE > 0, rate is number of frames per second,
DATA_RATE < 0, rate is negative of seconds per frame)
Duplicated PMU/DC Configuration
PMU Menu
PMUDC Summary
PMUDC Detail
PMUDC Stats

Using PMU data in the EMS

- State Estimator
  - More software enhancements needed?
  - PMU Data validation
  - New tuning concepts
- Link data to one-lines or other displays
- Other EMS visualization software options?



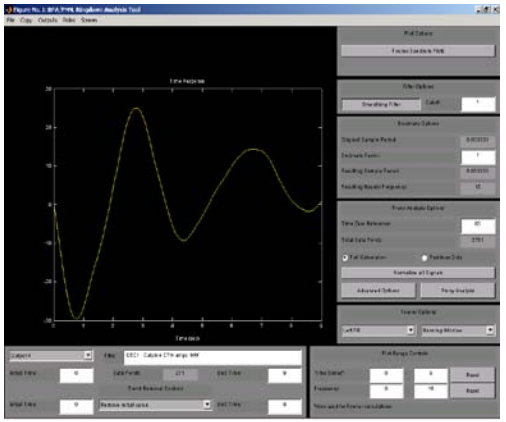
EMS Security Issues

- PDC streams data to a fixed UDP port
- Data requests not initiated from within ESP
- Location of PDC may be outside the ESP
  - Addition of PMUs may require multiple PDCs

EMS Security Options

- Due diligence documentation - benefits / risks
- Different PDC with enhanced security features
- Develop PDC to RTU interface
- Other?

Technical Efforts



- Phasor data validation
  - Comparison of EMS data trends with other PMU clients
  - Measured vs SE computed phase angle differences
- Incorporation of additional Phasor data
  - New PMU's
  - Upgrade PMU's to support newest draft

EMS Technical Efforts

- Establish EMS Standards
  - Naming conventions
  - Scaling factors
  - New calculations
- Consider exchange of phasor data with other utilities
- Establish SE Tuning concepts for best utilization

EMS Conclusions

- PMU data becoming more widespread
- SE utilization:
  - software changes
  - tuning efforts
- Security issues exist and must be addressed

Thank you !

QUESTIONS ?