

*Peak Reliability*  
*Delivering near real-time phase angle deltas*  
*using Inter-Control Center Communication*  
*Protocol (ICCP)*

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PEAKRELIABILITY

# *Peak Reliability Synchrophasor Program (PRSP)*

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# Goals

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- Improve PMU data availability
- Improve PMU data accuracy
- Improve PMU Registry
- Increase PMU data sharing
- Increase PMU data usage in the control room
- Use PMU data in automated controls
- Use PMU data in Voltage Stability application
- Use PMU data for Model Validation
- Develop base lining tools for PMU data



# *Increase PMU data sharing*

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- Investigate alternatives to C37.118 for wide area PMU data transmission
  - GPA SIEGate
- Investigate optimal network configuration for C37.118 PMU data transmission
  - UDP TCP
- Investigate sharing PMU data over ICCP
  - Phasors, Frequency, ROCOF
- Investigate sharing values calculated from PMU data over ICCP
  - Phase Angle Delta (PAD), MW, MVAR, Modal Analysis, Oscillation Detection



# *Increase PMU data usage in the control room*

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- Improve PMU data availability and accuracy
- Work with Reliability Coordinators on value add use cases
- Determine viability of shared WAV
- Determine possible actions and operational procedures based on PMU data
- Create member task team to discuss PMU data usage in the control room
- Investigate changes to Modal Analysis and Oscillation Detection applications and engines
  - Investigate common API for MAS engines
  - Investigate common displays for MA and OD
- **Investigate PMU data over ICCP to supplement SCADA/EMS**



# ICCP

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- IEC 60870-6
- The **Inter-Control Center Communications Protocol** (ICCP or IEC 60870-6/TASE.2) is being specified by utility organizations throughout the world to provide data exchange over wide area networks (WANs) between utility control centers, utilities, power pools, regional control centers, and Non-Utility Generators. ICCP is also an international standard: International Electrotechnical Commission (IEC) Telecontrol Application Service Element 2 (TASE.2).



# *ICCP used in the Western Interconnect*

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- Send SCADA measurements between entities
- Measurements are not time stamped
- Measurements are not synchronous
- Report rate from 1 sample every 4 seconds to 1 sample every 20 seconds



# *ICCP and PMU raw data*

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- Voltage and Current RMS values
  - Backup for EMS/SCADA ICCP values
- Phasors
- Frequency
- Frequency Rate of Change





# *ICCP and PMU raw data questions*

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- Optimal report rate
- What happens if the PMU data does not match the SCADA data
- Does it matter if the measured values are not time stamped
- Is there any value in sending raw phase angle values
- Any uses for frequency or frequency rate of change



# *ICCP and PMU calculated values*

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- MW and MVAR
  - Calculated at the PMU for lines can be used as a backup for SCADA data values
  - Calculated by applications at control centers
- Mode Damping
  - Calculated by applications at control centers
- Oscillation Detection
  - Calculated by applications at control centers
- Phase angle delta
  - Calculated by applications at control centers



# *ICCP and PMU calculated values questions*

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- Optimal report rate
- What happens if the calculated values do not match the SCADA data
- Does it matter if the calculated values are not time stamped

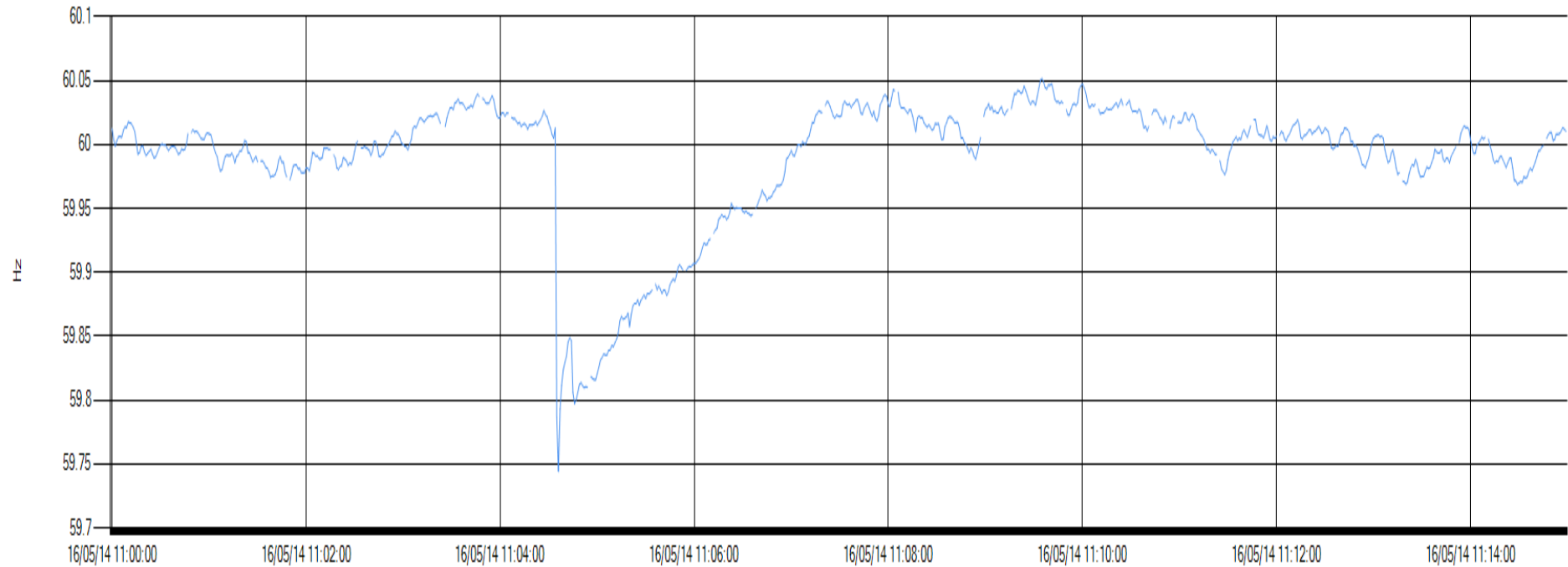


# EXAMPLES OF 4 SECOND PMU DATA



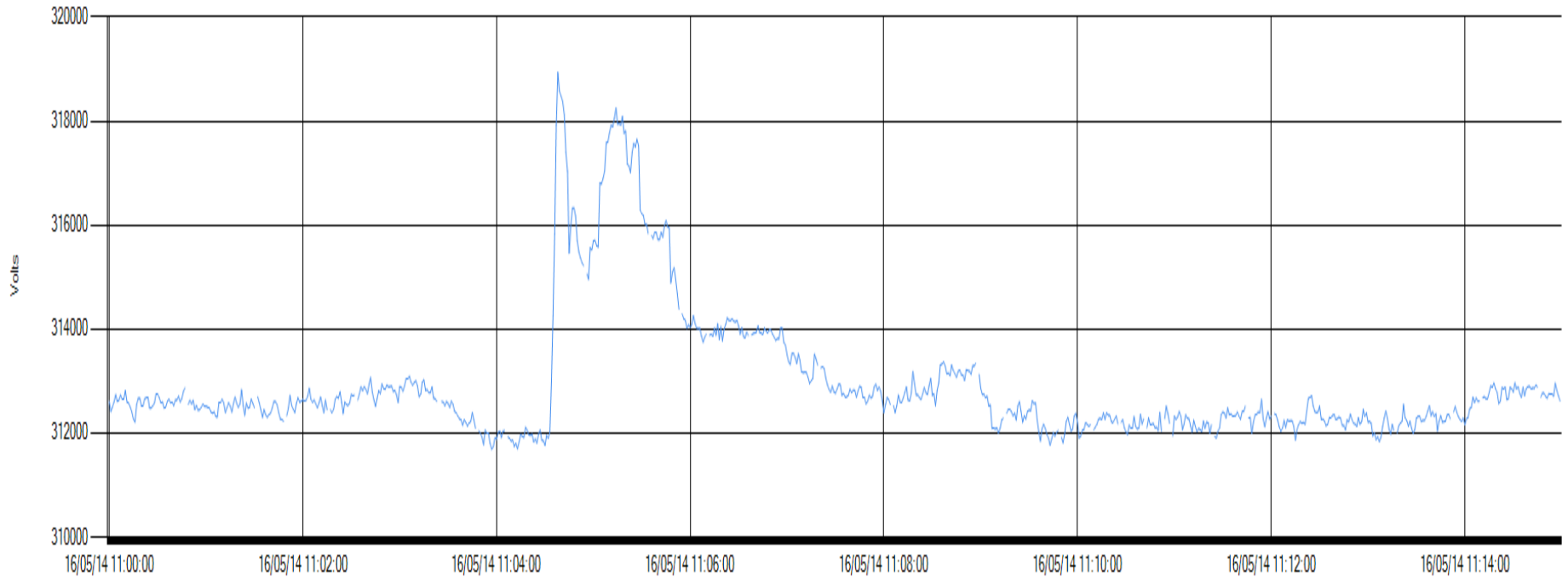
# Frequency event at 4 second report rate

W001BIG\_EDDY\_01:A500FREQ\_\_\_1F\_



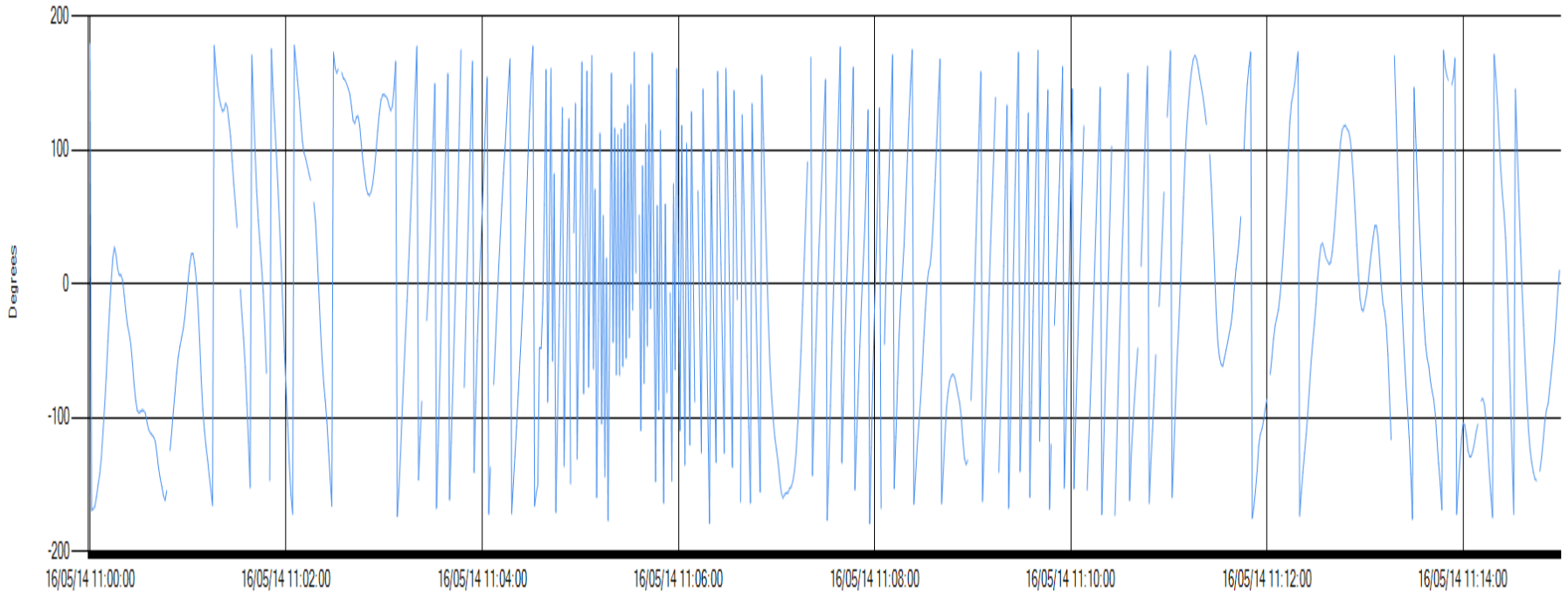
# *RMS Voltage at 4 second report rate*

— W001BIG\_EDDY\_01.B500WEST\_\_\_1VP



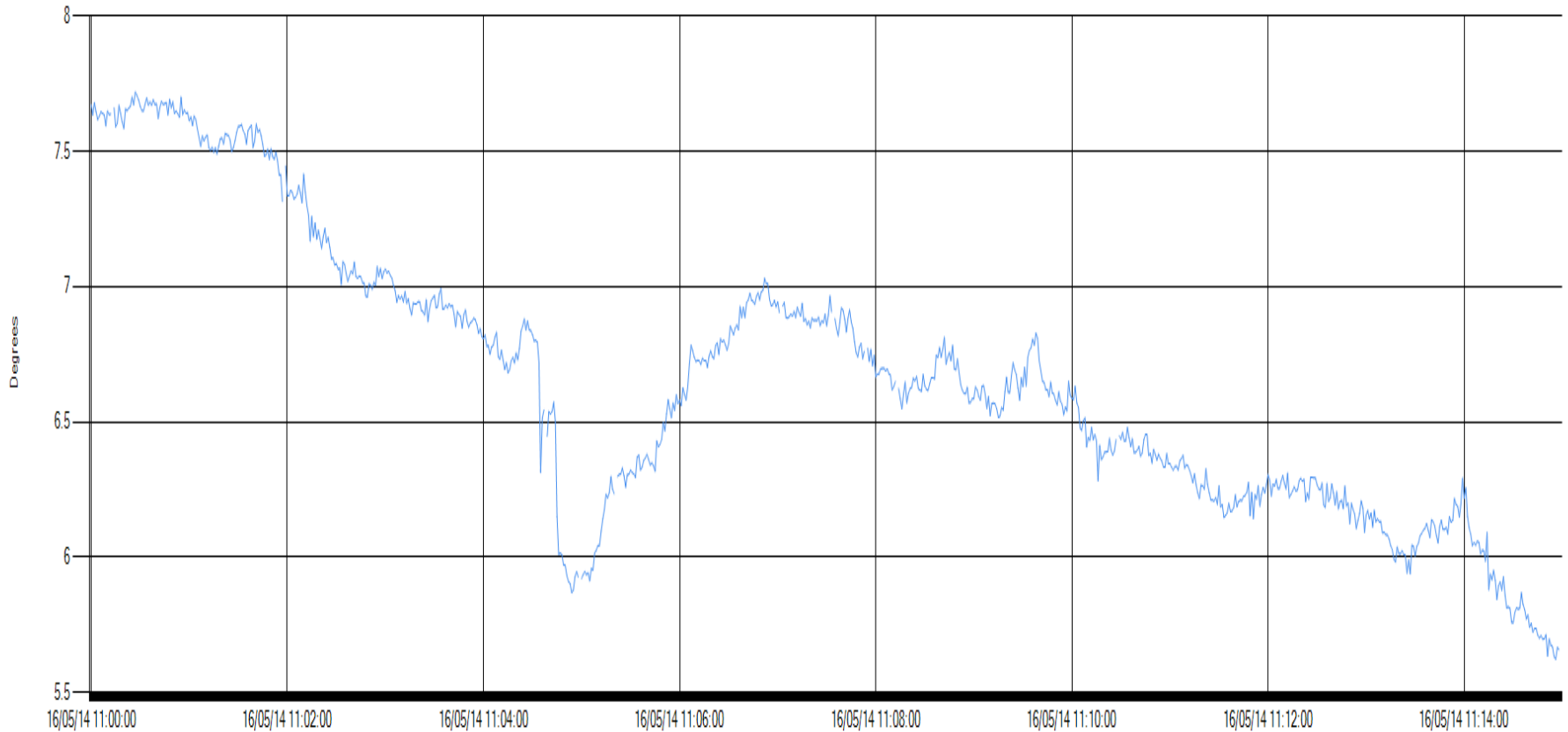
# *Phase Angle at 4 second report rate*

W001BIG\_EDDY\_01:B500WEST\_\_\_1VP



# Angle Delta 4 second report rate

Delta: W066W/ESTVING\_\_02:8500NORTH\_\_1VP-W084W/VALLY\_\_01:1500MIGUEL\_\_1VP





# *Phase angle delta from PMU data*

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- Calculate the angle between two buses
- Available from PMU raw data because the measurements are synchronized
- PMU measured angles are discontinuous because the measurement is a reference to a perfect 60 Hz sine wave. Since the system rarely operates at exactly 60 Hz the measured angles shift every measurement. This shift results in a measurement that is discontinuous. When an angle reaches +180 degrees, it wraps to -180 degrees and conversely for decreasing angles. An angle will reach  $\pm 180$  degrees about every 20 seconds for a 0.05 Hz offset from nominal frequency, as a result discontinuities in angle differences will appear frequently. The voltage angle delta between two buses will also be discontinuous if the angles or the delta is not unwrapped.



# When to Unwrap

*Each angle prior to calculating delta*

```
// Unwrap all source angles
for (int i = 1; i < sourceAngles.Length;
i++)
{
    dis0 = Math.Abs(sourceAngles[i] +
offset - unwrappedAngles[i - 1]);

    dis1 = Math.Abs(sourceAngles[i] +
offset - unwrappedAngles[i - 1] + 360.0D);

    dis2 = Math.Abs(sourceAngles[i] +
offset - unwrappedAngles[i - 1] - 360.0D);
    if (dis1 < dis0 && dis1 < dis2)
        offset = offset + 360.0D;
    else if (dis2 < dis0 && dis2 < dis1)
        offset = offset - 360.0D;
    unwrappedAngles[i] = sourceAngles[i] +
offset;
}
```

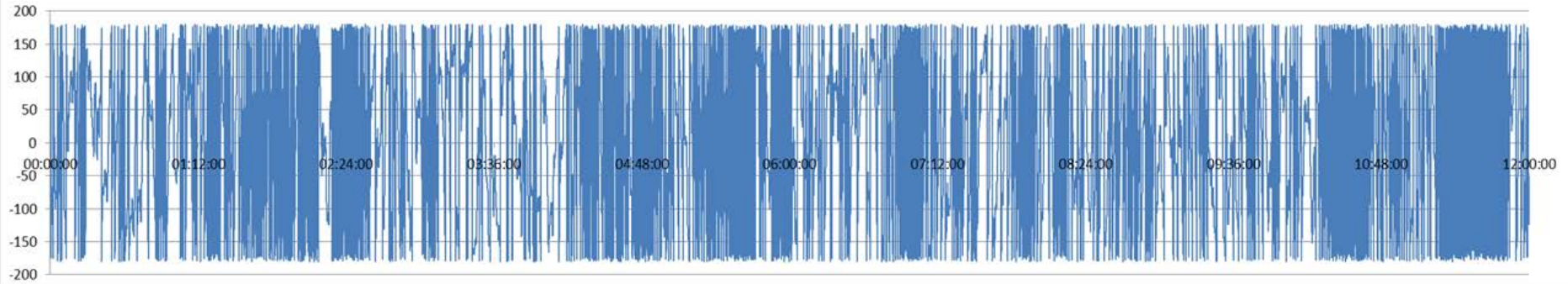
*Unwrap the delta*

```
double UnwrapAngleDelta(double AngleDelta)
{
    double rval = AngleDelta;
    if (Math.Abs(AngleDelta) > 180)
    {
        if (Math.Sign(AngleDelta) < 0) //
is AngleDelta negative?
            { rval = AngleDelta + 360; }
        else // AngleDelta is positive
            { rval = AngleDelta - 360; }
    }
    return (rval);
}
```

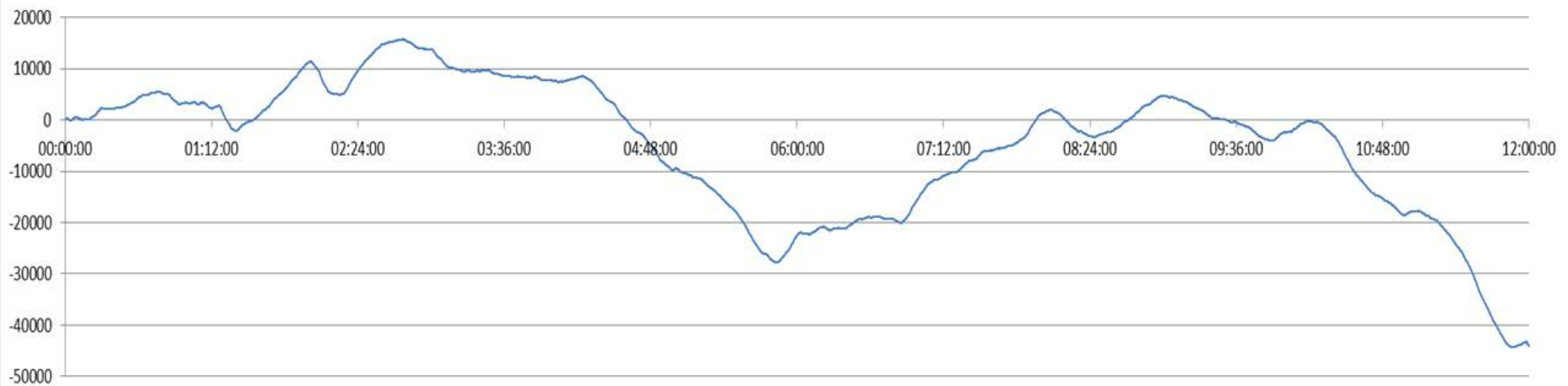


# Phase Angle Delta Angle 1

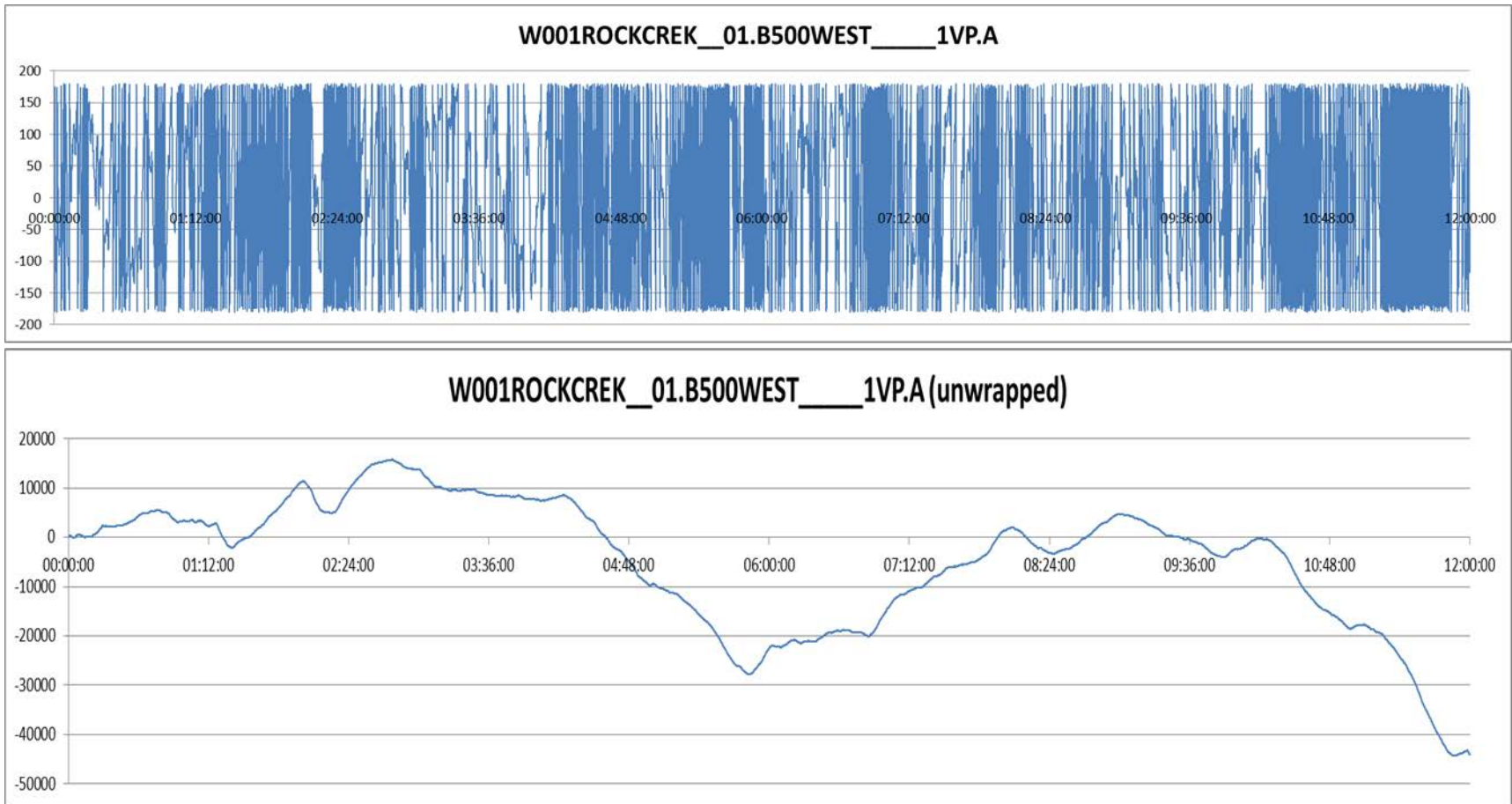
W001ALLSTON\_\_01.B500NORTH\_\_1VP.A



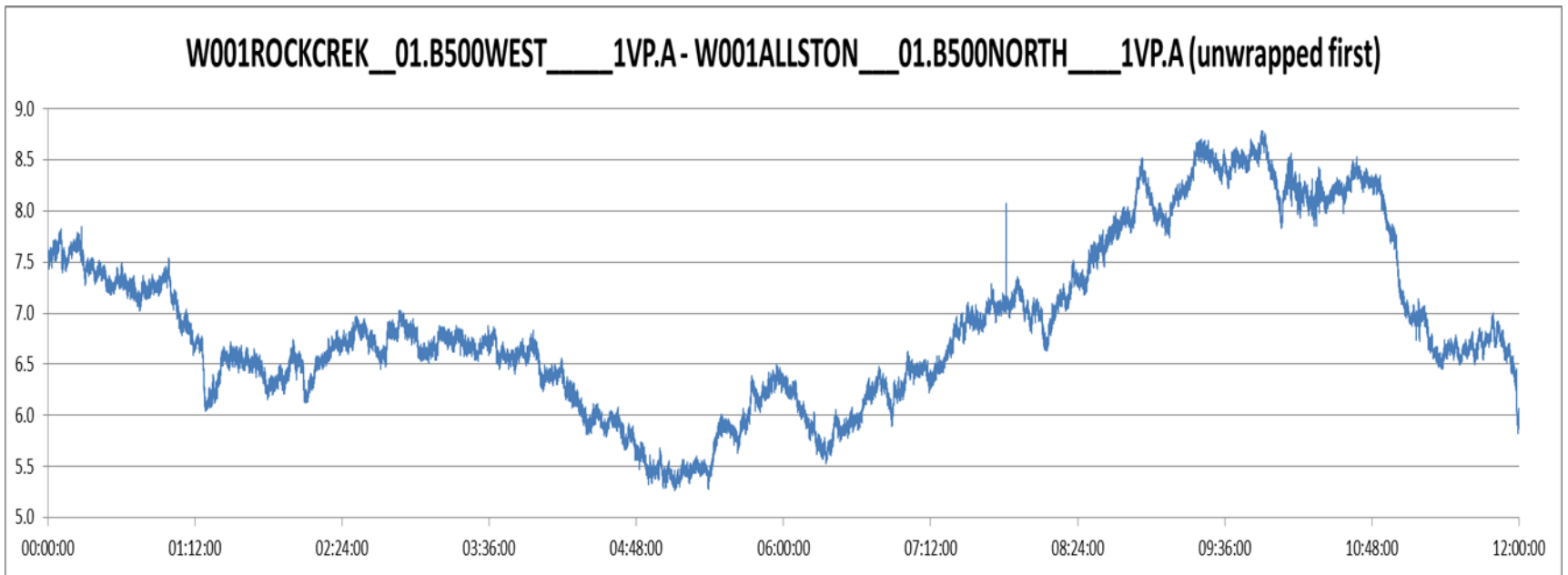
W001ALLSTON\_\_01.B500NORTH\_\_1VP.A (unwrapped)



# Phase Angle Delta Angle 2



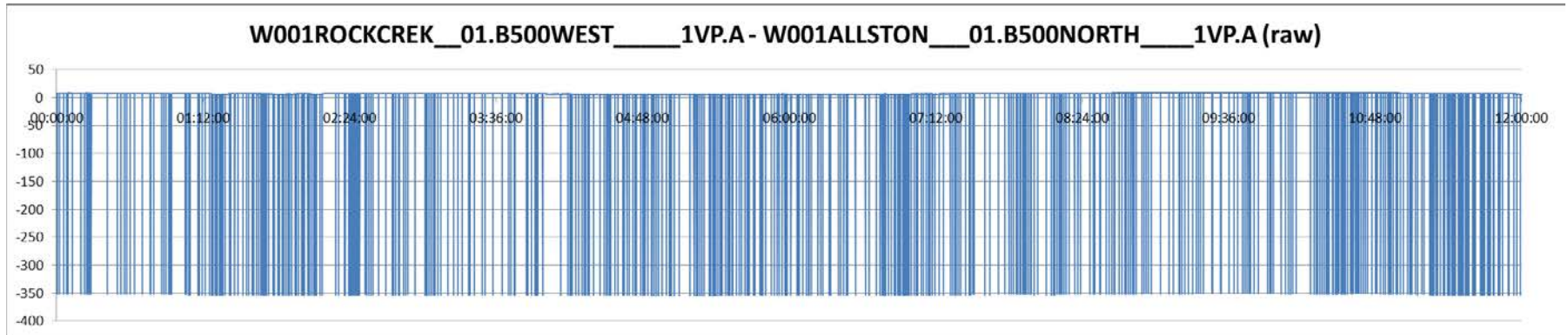
# Phase Angle Delta result



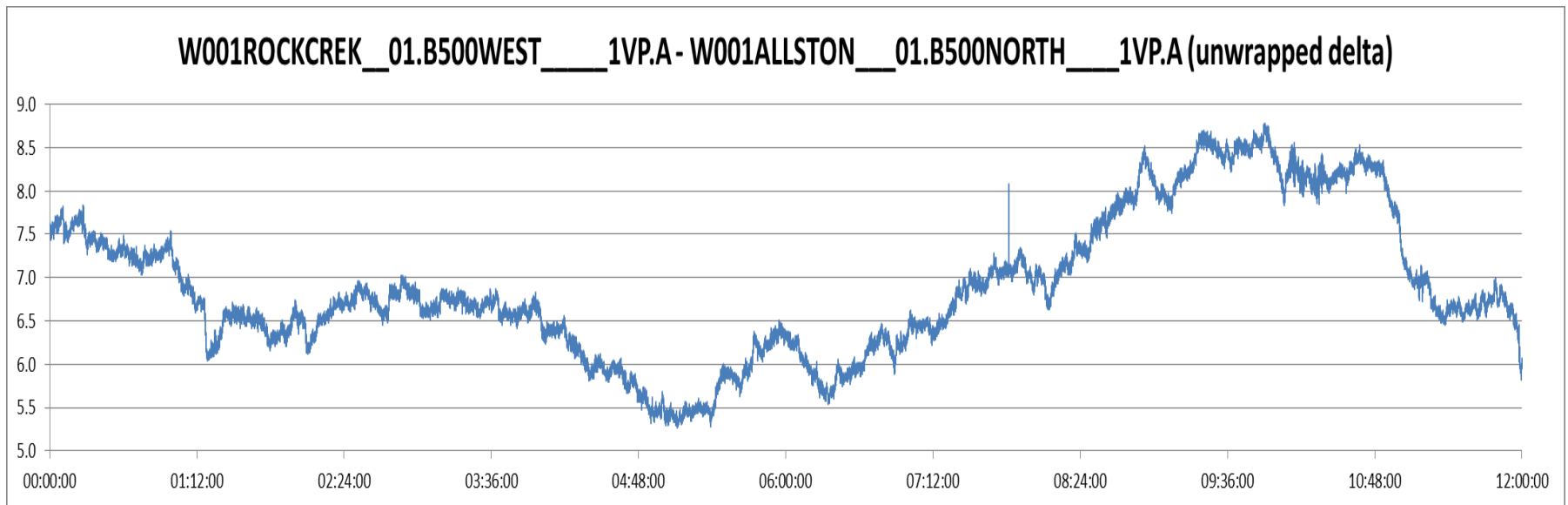
Phase angle delta as a result of subtracting one unwrapped phase angle from another



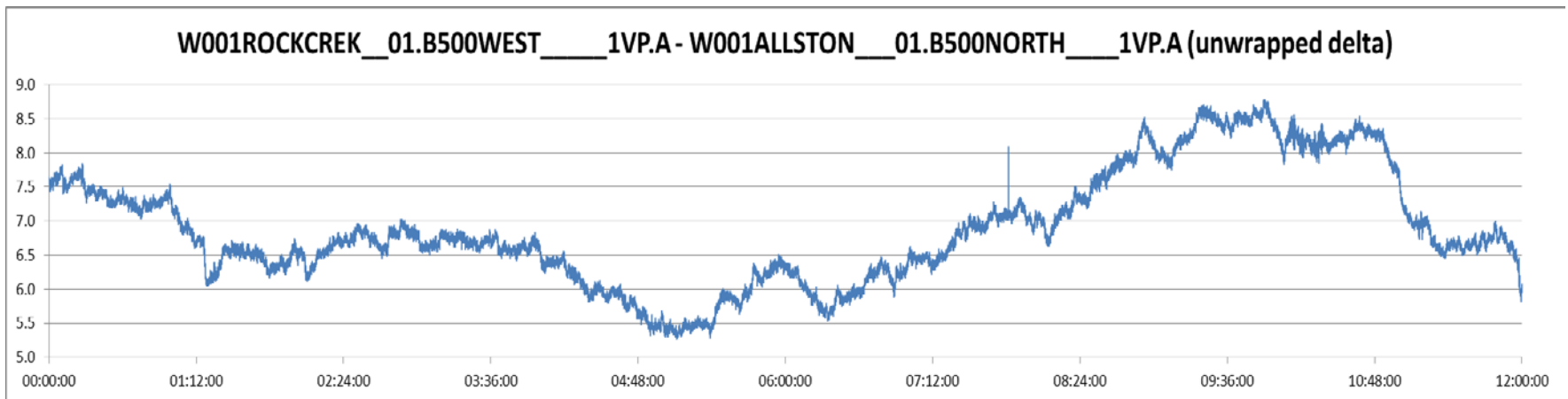
# Subtract First



Then Unwrap the result



# Compare the results



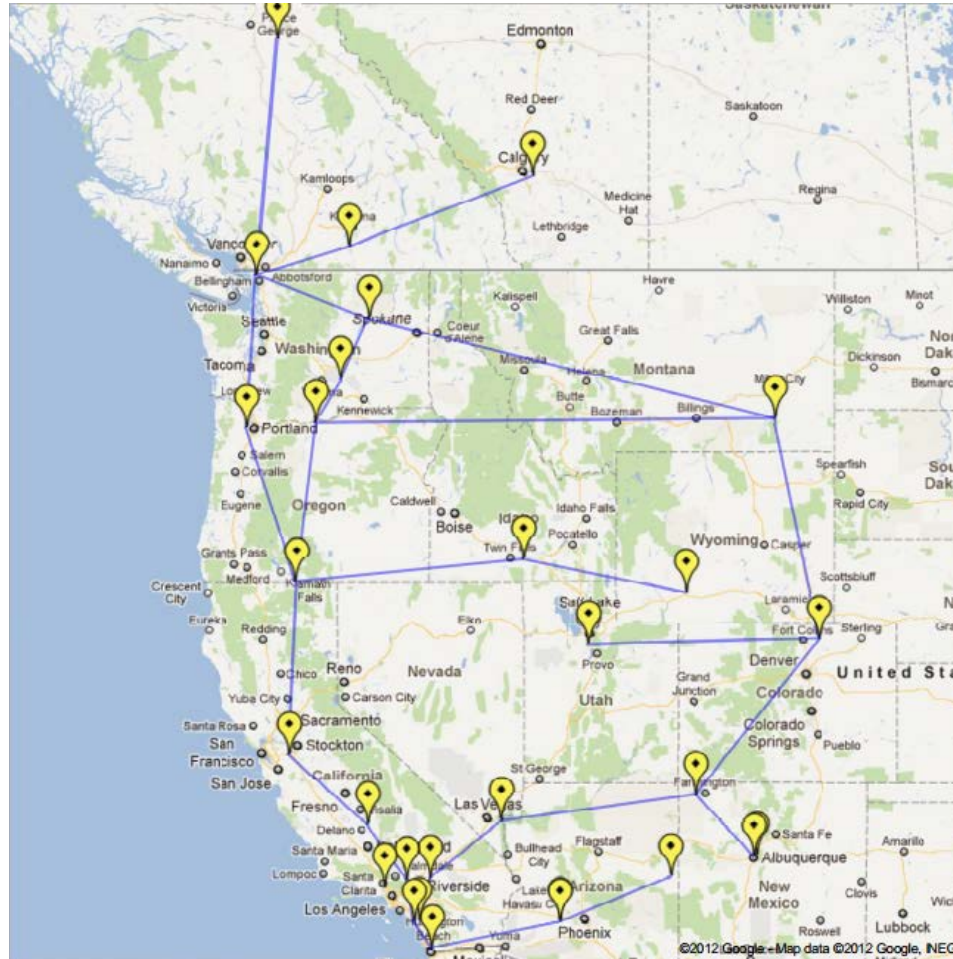


# Phase Angle Pairs Southwest





# Phase angle pairs Western BES



# *PRSP Deliverables*

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- Work with WECC Joint Synchronized Information Subgroup (JSIS), Peak RC engineering, and Peak RC members to:
  - Determine viability of delivering PMU data over ICCP
  - Determine which PMU data measurements to send over ICCP
  - Determine which PMU derived data values to send over ICCP
  - Determine optimal report rate
  - Determine list of phase angle pairs
  - Encourage deployment of additional Bus Voltage measurements where they would be useful
  - Develop work stream documentation for requesting PMU data over ICCP
  - Determine correct method of calculating phase angle delta i.e. subtract then unwrap or unwrap first





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