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

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Goals

- 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

- 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

- 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

- 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

• 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

• Voltage and Current RMS values
  – Backup for EMS/SCADA ICCP values
• Phasors
• Frequency
• Frequency Rate of Change
ICCP and PMU raw data questions

- 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

• 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

- 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
RMS Voltage at 4 second report rate
Phase Angle at 4 second report rate
Angle Delta 4 second report rate
Phase angle delta from PMU data

- 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 ±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++)
{
    double dis0 = Math.Abs(sourceAngles[i] + offset - unwrappedAngles[i - 1]);
    double dis1 = Math.Abs(sourceAngles[i] + offset - unwrappedAngles[i - 1] + 360.0D);
    double 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

W001ROCKCREK_01.B500WEST___1VP.A

W001ROCKCREK_01.B500WEST___1VP.A (unwrapped)
Phase Angle Delta result

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

Then Unwrap the result

W001ROCKCREK__01.B500WEST____1VP.A - W001ALLSTON__01.B500NORTH____1VP.A (raw)

W001ROCKCREK__01.B500WEST____1VP.A - W001ALLSTON__01.B500NORTH____1VP.A (unwrapped delta)
Compare the results
Phase Angle Pairs Southwest
Phase angle pairs Western BES
PRSP Deliverables

• 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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