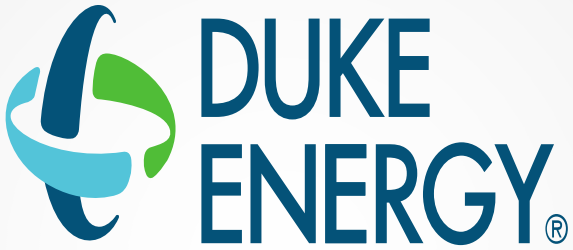


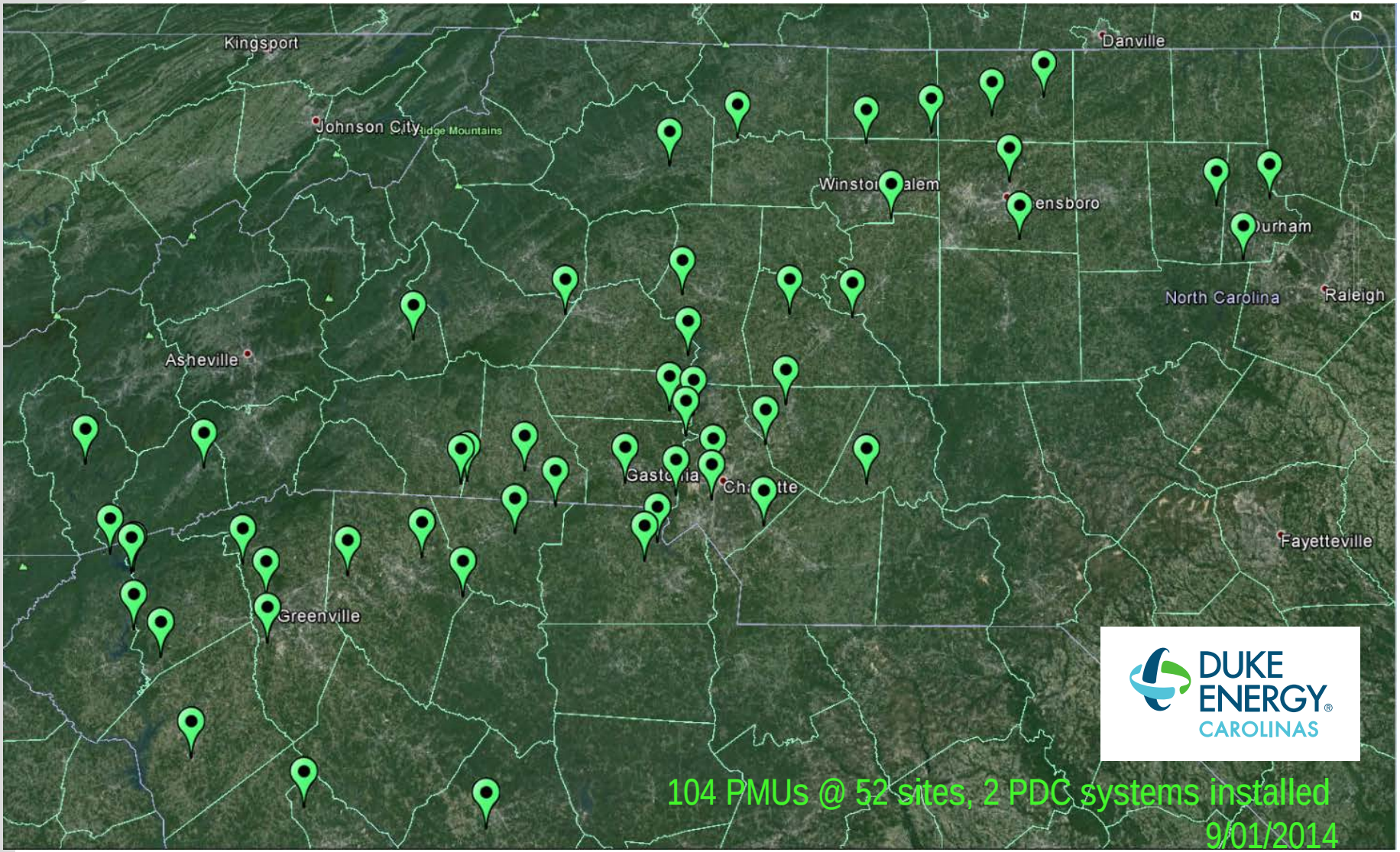
Data content as of August 2014
NASPI Work Group Meeting
October 22-24, 2014

Duke Energy Carolinas - Insights on Operations Solutions

- Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number(s) DE-OE0000374

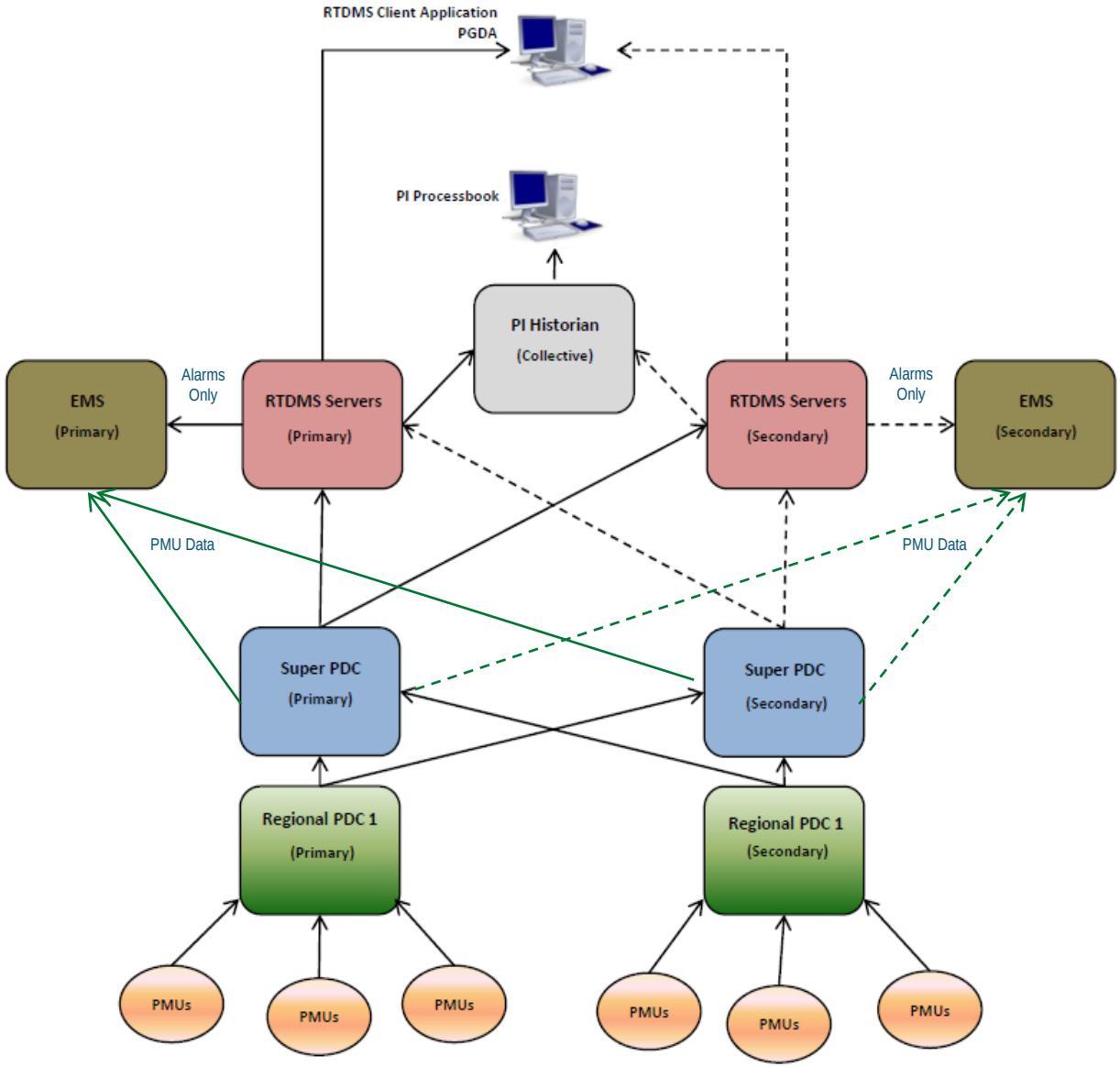
- Duke Energy Carolinas
  - Megan Vutsinas, Megan.Vutsinas@duke-energy.com, 704-382-0855
  - Tim Bradberry, Tim.Bradberry@duke-energy.com, 704-382-4728
- Vendors: Alstom Grid, SEL, Cisco, OSIsoft, EPG

Project Map


Kingsport
Johnson City
Danville
Asheville
Greenville
North Carolina
Raleigh
Fayetteville
DUKE ENERGY CAROLINAS
104 PMUs @ 52 sites, 2 PDC systems installed 9/01/2014

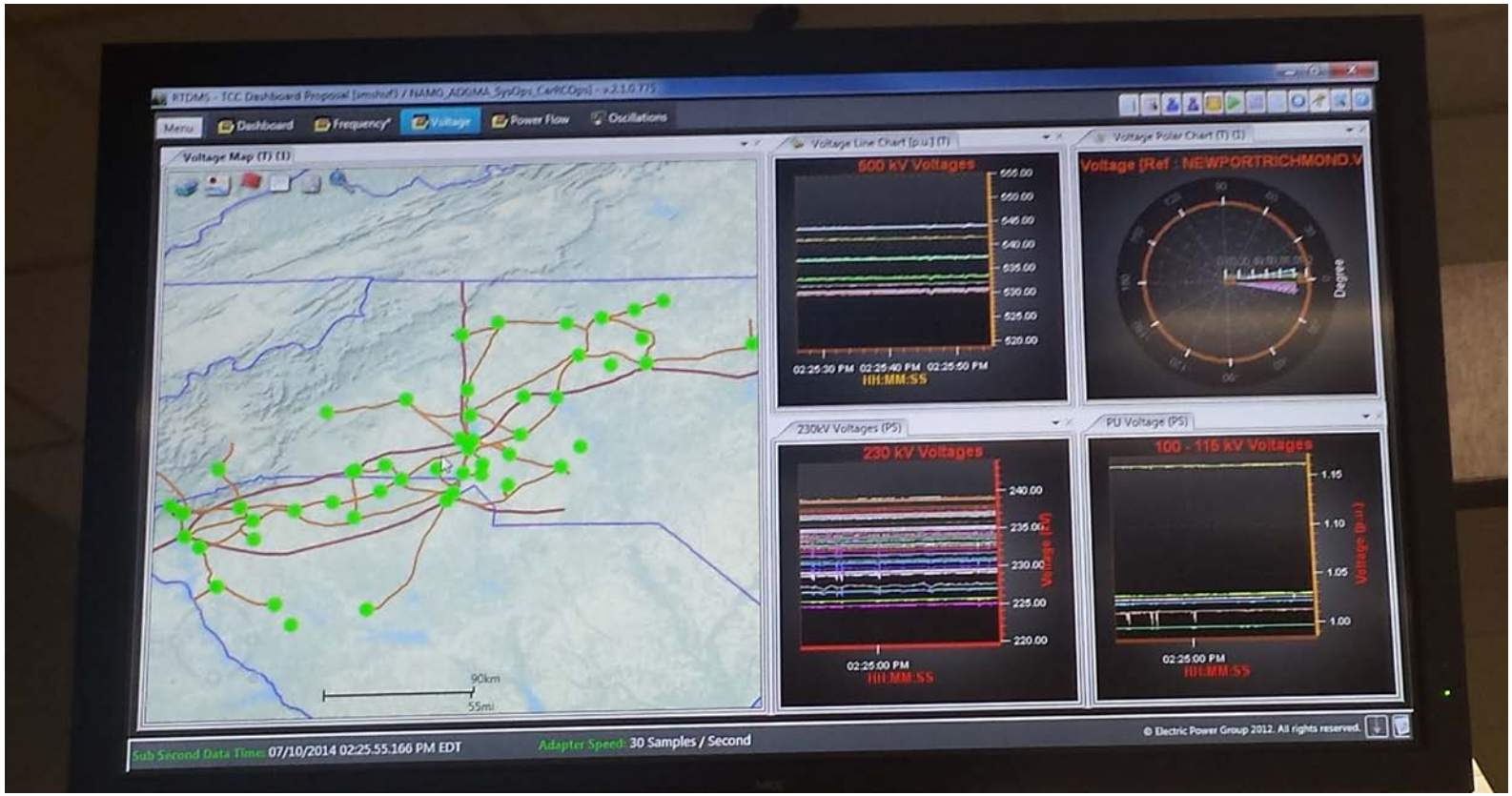
- Control Room Usage
  - Visualization software deployed spring 2014,will include alarms sent to EMS
  - Integration with State Estimator
  - Redundant measurements in SCADA applications
- Planning Usage
  - Event analysis
  - Model tuning (generator parameters, frequency response, etc)
- PMUs installed at one distribution (solar) facility
  - “seeing what we get”

Carolinas Architecture



- Deployed in Control Room Spring 2014
- No current operating procedures/guides, strictly monitoring currently
- Able to see system behavior not previously observed
  - Not all oscillations are “bad” oscillations
  - Currently operators notify engineers of “abnormal” behavior

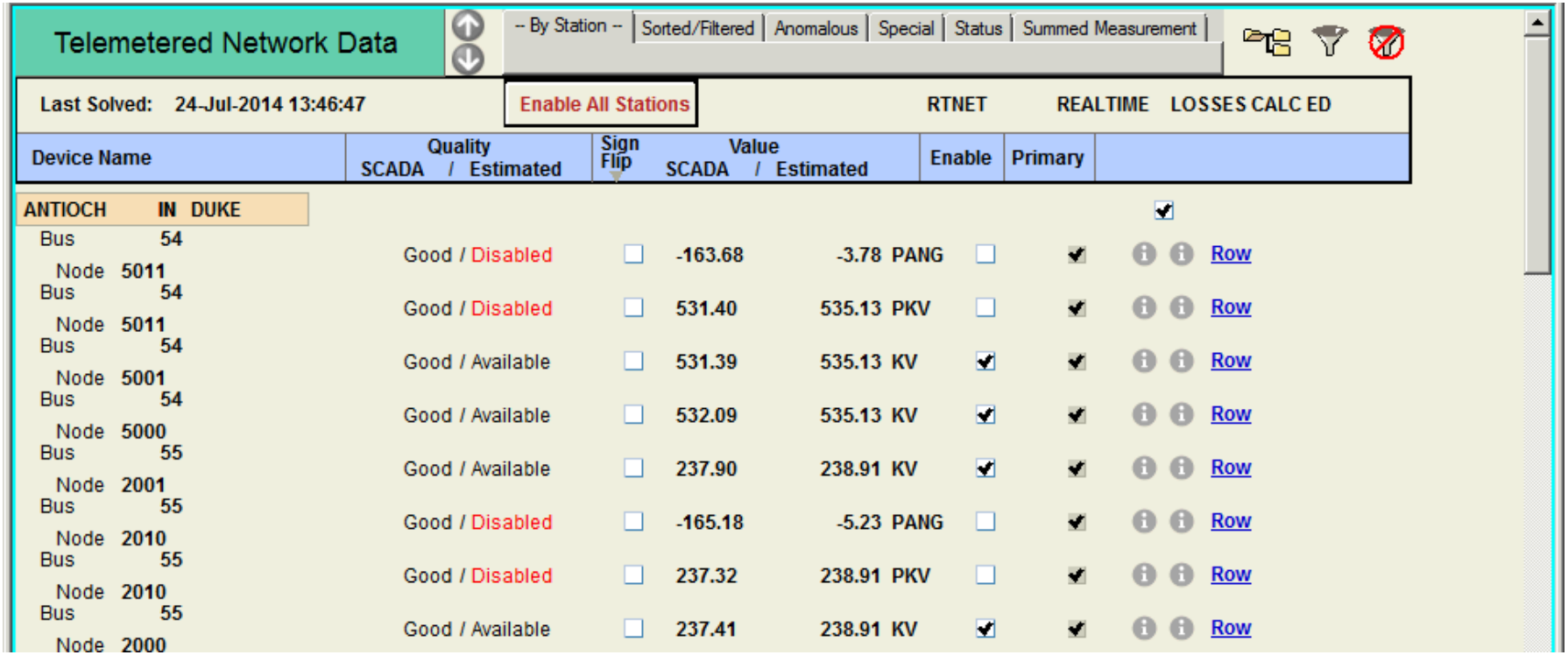
- Dedicated monitor



- Targeted 2015, proof of concept complete
- Additional DNP3 input configured to EMS
- ONLY alarms not available via the EMS
  - RTDMS still alarms on all, but only certain selected
  - Want to maximize value to operator
  - Examples: angle differences, oscillations
  - Alarms refer the user back to RTDMS for further analysis

- Pilot project involves combining SCADA and phasor measurements into the traditional WLS estimator
- Solution rate of 99.8% prior to PMU incorporation, don't expect to see significant improvement
- Expect PMUs to provide measured angle values, redundant measurements for SCADA

- Internal Angles center around zero



- Reference bus is currently Allen
  - assumed zero degrees

Network Island Summary

Min Bus Number: for an Island: 8

1 TOPOLOGY ISLANDS

RTNET Last Solved: 24-Jul-2014 14:24:47 RTNET REALTIME LOSSES CALC ED

#	Reference Bus - Station	KV	Number	Swing Generator	MW Online Capacity	MW Generation	MW Load	Number of Buses	Number of Branches	MW Losses	MW Mismatch	MW HVDC	Solution Status Converged	IterMax	DIV	No V Re
1	ALLEN	16	32	UN_3	309757.94	173119.61	168876.92	7767	11340	4503.19	260.55	0.00	✓			

Network Bus Summary

-- Bus Symbolic View -- | Bus List View

Bus: 32 Island: 1 Solved 16.0 KV 0.999 PU 0.0 DEG Remove Show Nhood

V Meas Observable MEAS 16.0 KV 0.999 PU

XF Remove 0 BK3A To Station: ALLEN

252.0MW 62.6MR XF2: BK3A

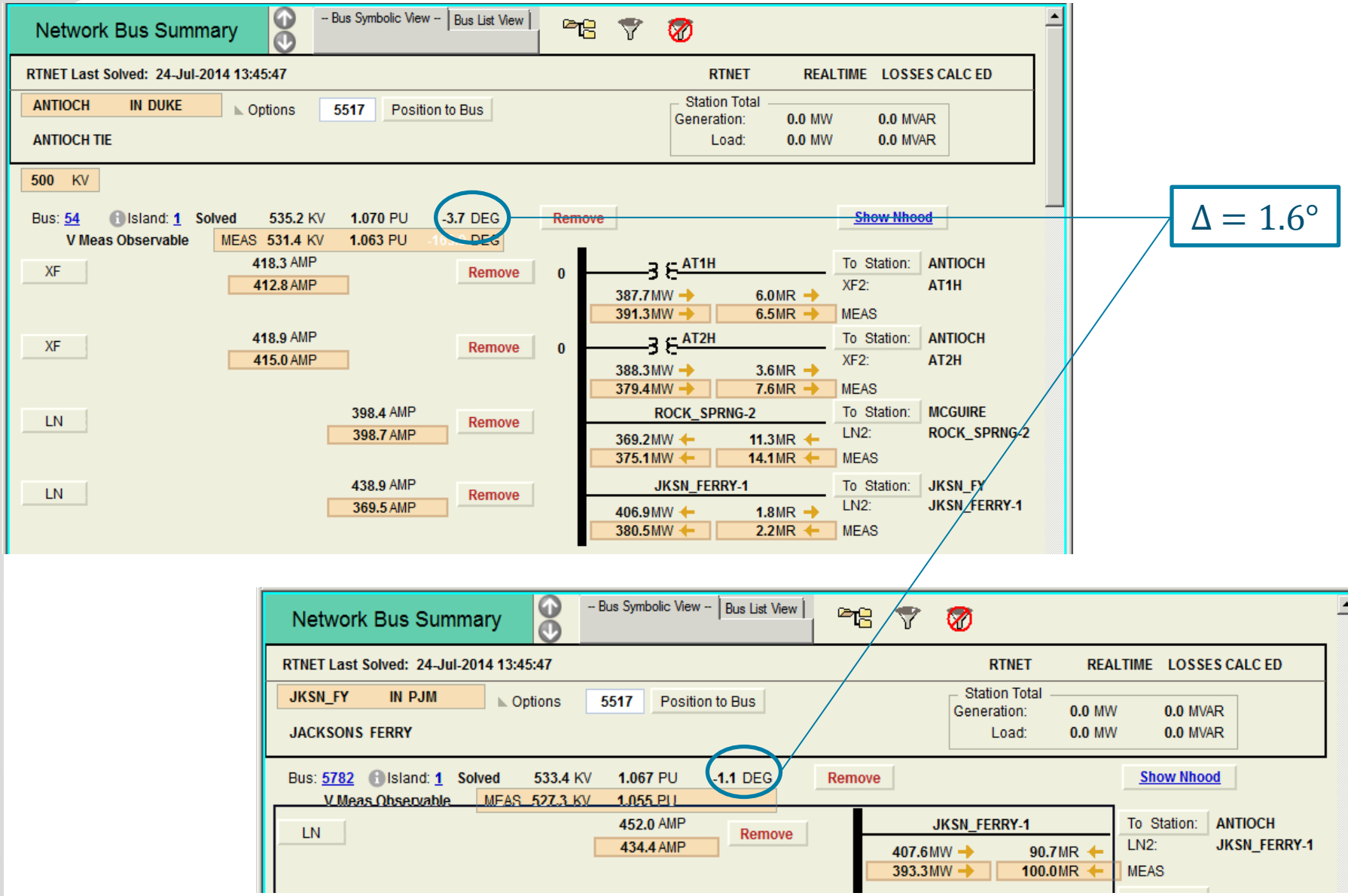
AUX Remove AUX3

15.2MW 15.2MR

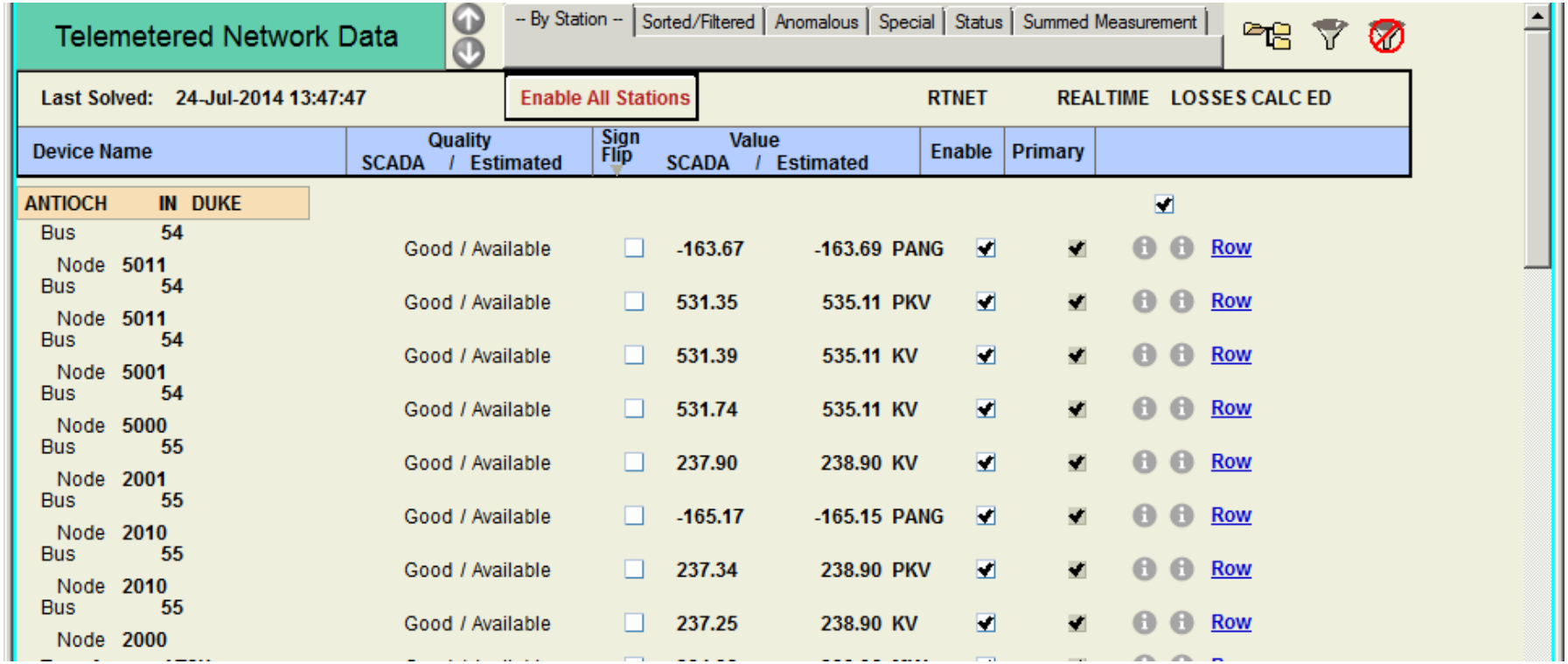
Unit UN_3 267.2MW 77.8MR G Remove

269.7MW 77.2MR MEAS

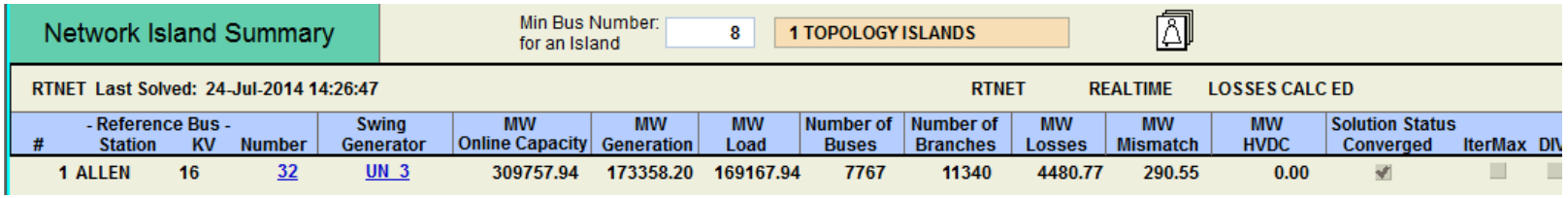
RTNET Solution without PMUs

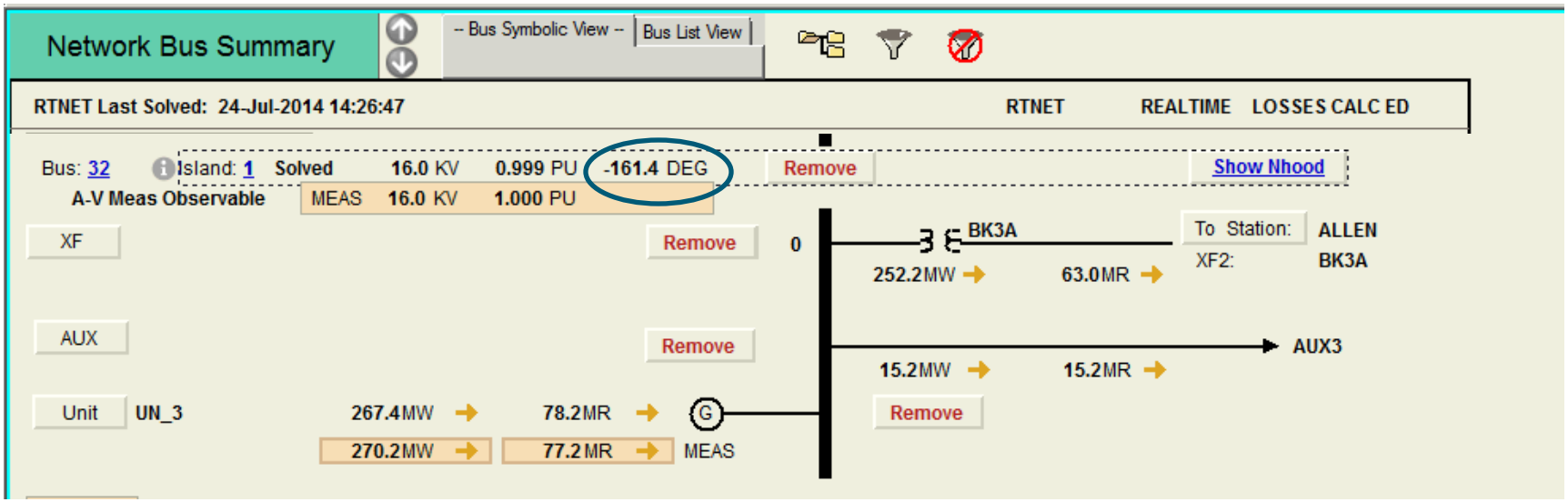


- Internal Angles “skewed” to around 150

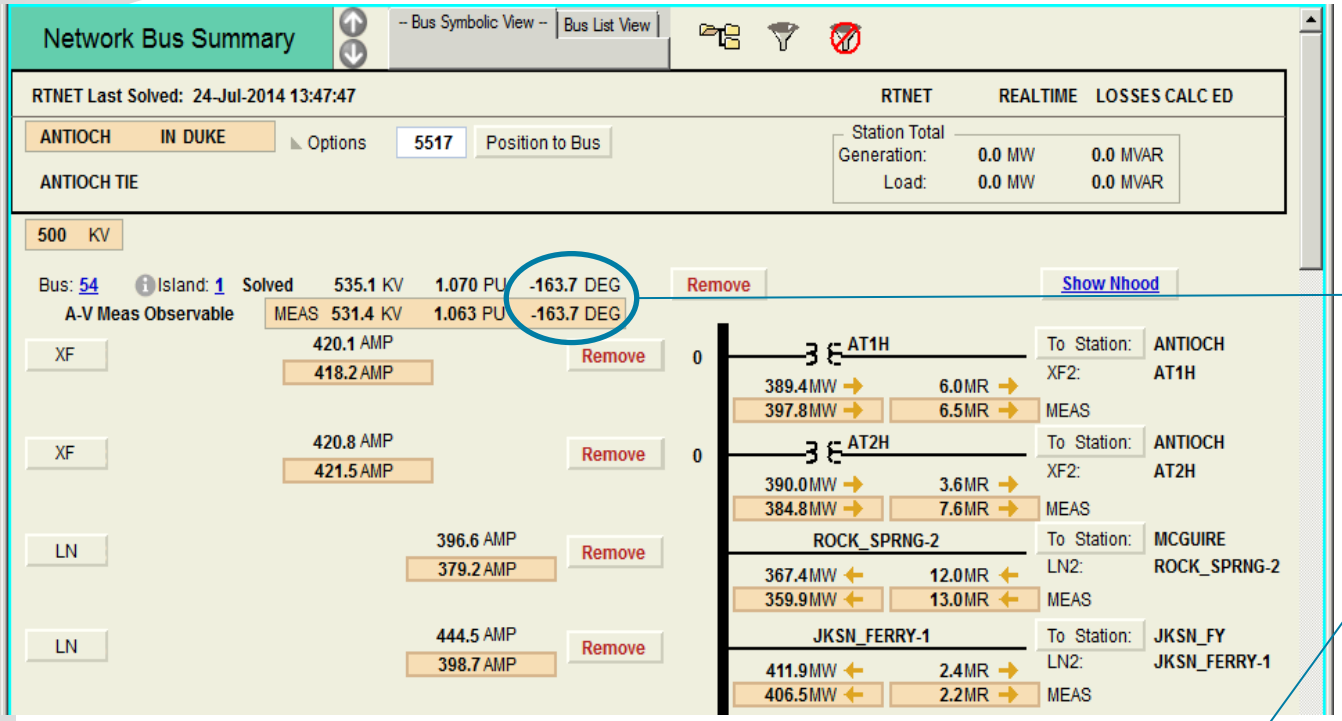


- Reference bus is still Allen
  - Since there are measured angles now, no angle is assumed for the reference.
  - PMU reference is configured in the ISD adapter in the PDC

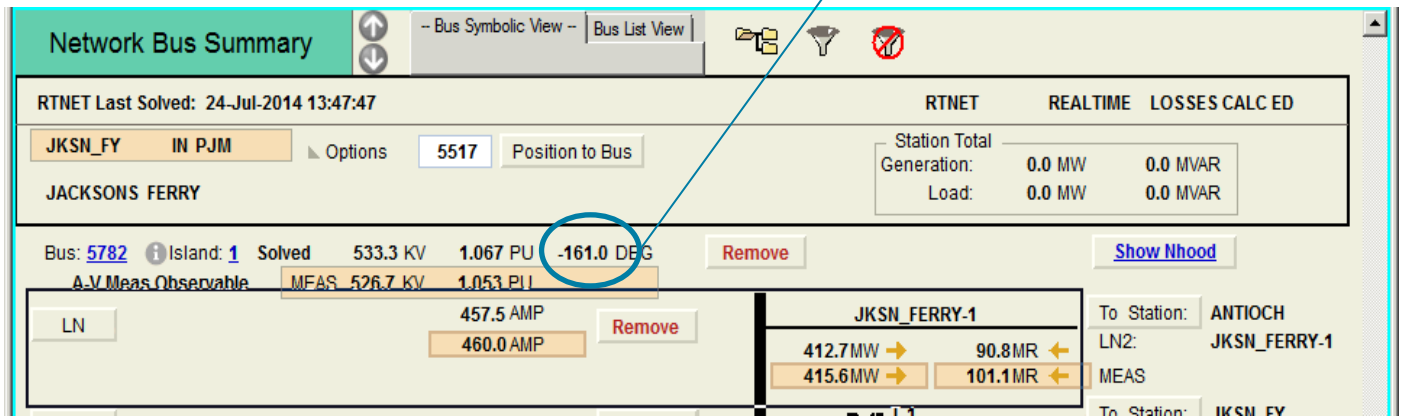




RTNET Solution with PMUs



Δ= 1.7°



- Delta Angles stay the same, though individual angle values are “skewed”
- Cost (Error) remains the same before and after PMU measurements are enabled
- Not giving phasors higher accuracy weight