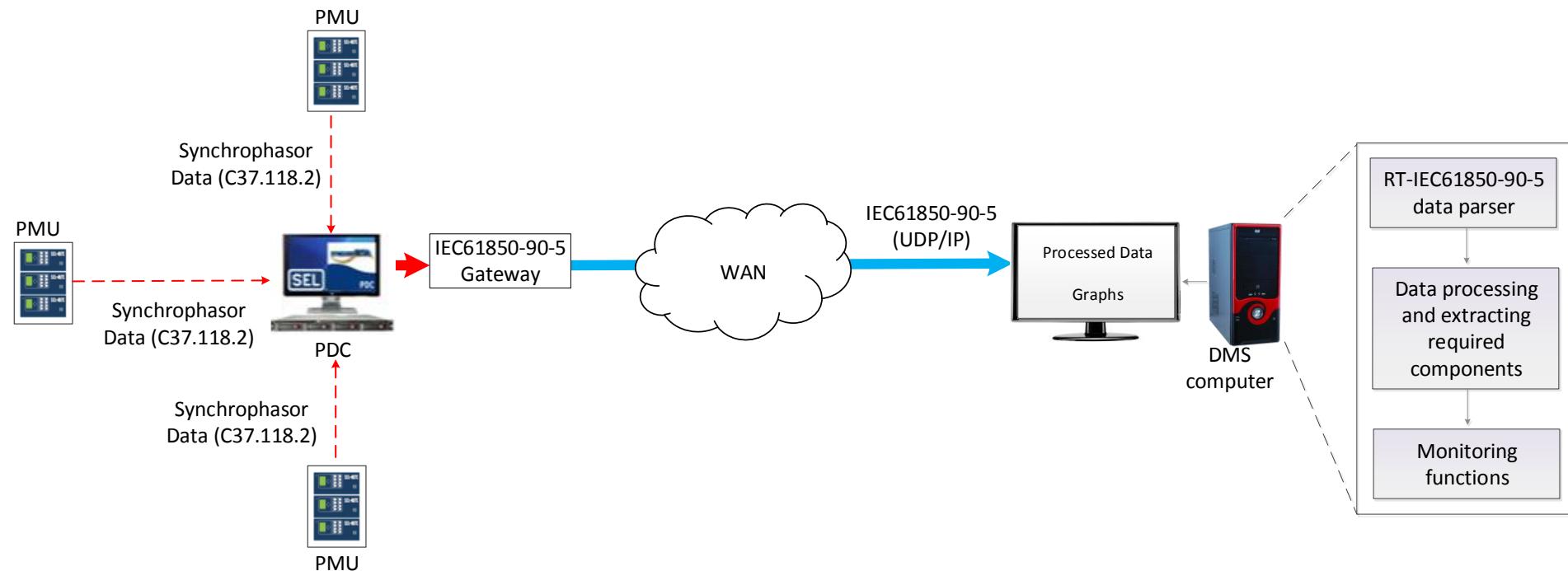


Interfacing TSOs and DSOs via PMU-based information exchange



Data Flow



IEC 61850-90-5 Gateway

for

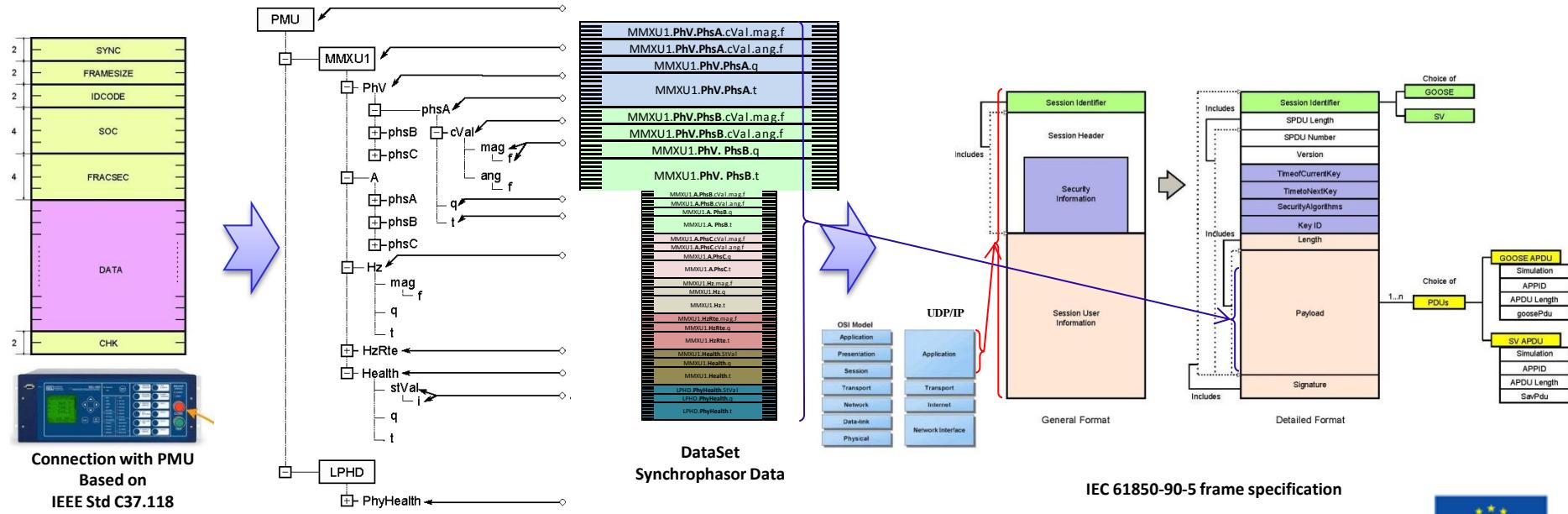
IEEE C37.118.2 Synchrophasor Data Transfer



- **Theory:**

- **IEEE C37.118** → Synchrophasor data transfer by exchange of 4 types of messages:
 1. Data, 2. Configuration, 3. Header and 4. Command Frames
- **IEC 61850-90-5** → PMU data (Based on C37.118) mapped to IEC 61850 Data Model
 - Communication mechanism: Routed-Sampled Value and Routed-GOOSE → Multicast UDP/IP

(1) IEEE C37.118 PMU Data → (2) IEC 61850 Data Model & Dataset → (3) IEC 61850 Routed-Sampled Value / GOOSE Publisher and (4) Subscriber



• Implementation and Results

• HIL Real-time simulation → SmarTS Lab

- Conformance of the functionality of the library with the requirements of IEEE C37.118.2 and IEC 61850-90-5 is validated.

Values of Data Frame:

```

Frequency of PMU 1 = 49.999992
ROCOF of PMU 1 = 0.000000
Phasor 1 of PMU 1 -> Channel Name = Ua
Phasor 1 of PMU 1 -> Magnitude = 0.999710
Phasor 1 of PMU 1 -> Angle = 86.401123
Phasor 2 of PMU 1 -> Channel Name = Ub
Phasor 2 of PMU 1 -> Magnitude = 0.999729
Phasor 2 of PMU 1 -> Angle = -33.601955
Phasor 3 of PMU 1 -> Channel Name = Uc
Phasor 3 of PMU 1 -> Magnitude = 0.999703
Phasor 3 of PMU 1 -> Angle = -153.601456
Phasor 4 of PMU 1 -> Channel Name = Ia
Phasor 4 of PMU 1 -> Magnitude = 1.745339
Phasor 4 of PMU 1 -> Angle = 116.315025
Phasor 5 of PMU 1 -> Channel Name = Ib
Phasor 5 of PMU 1 -> Magnitude = 1.220358
Phasor 5 of PMU 1 -> Angle = -134.544440
Phasor 6 of PMU 1 -> Channel Name = Ic
Phasor 6 of PMU 1 -> Magnitude = 1.281345
Phasor 6 of PMU 1 -> Angle = -14.711807

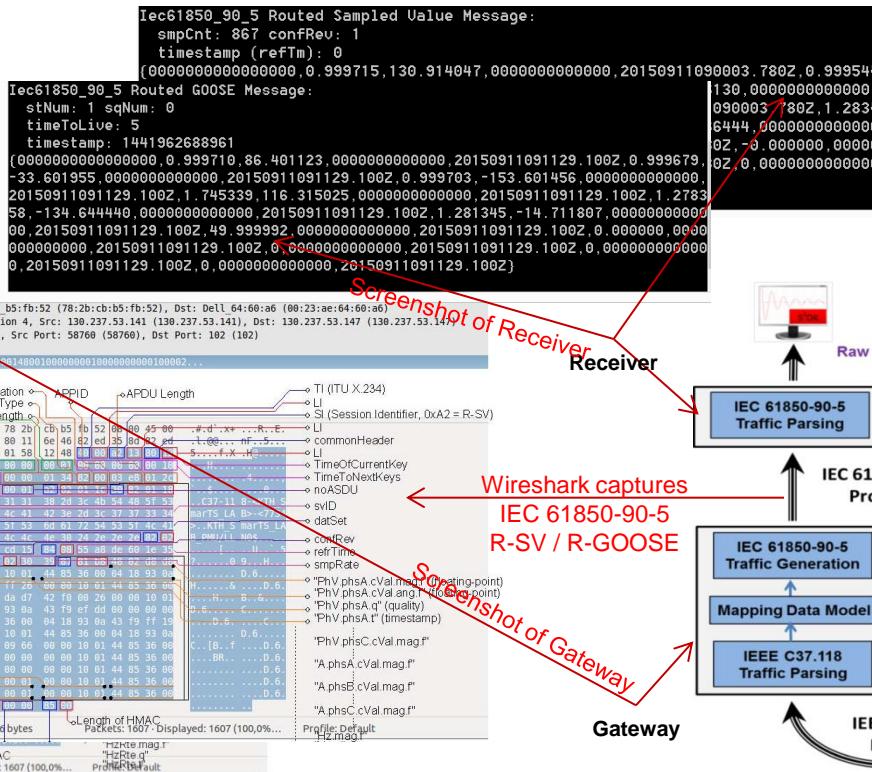
```

Security Algorithms:

```

goosePdu <0x40> [0x0000 00 23 ae] Version Number <0x0000 00 23 ae>
SPDU Number <0x01 01 bf 19> SPDU Length <0x01 01 93 e5>
Key ID <0x0200 35 93 e5> Security Algorithms <0x0030 00 81 80>
goosePdu <0x40> [0x0000 00 23 ae] sPdu <0x0000 00 23 ae>
Tag Byte <0x00> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> Tag Byte <0x00> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
Length <0x00> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> Length <0x00> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
timestamp <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> timestamp <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
ndcCom <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> confRev <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
test <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> test <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
DataSet <0x0040> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> DataSet <0x0040> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'Health stVal' <0x170> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> 'Health stVal' <0x170> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'Health t' <0x160> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> 'Health t' <0x160> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'Health c' <0x160> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> 'Health c' <0x160> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'PhyHealth stVal' <0x170> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> 'PhyHealth stVal' <0x170> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'PhyHealth q' <0x150> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> 'PhyHealth q' <0x150> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'PhyHealth H' <0x170> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> 'PhyHealth H' <0x170> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
'Signature' <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> Signature <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>
Length of HMAC <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00> Length of HMAC <0x0000> [0x00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00>

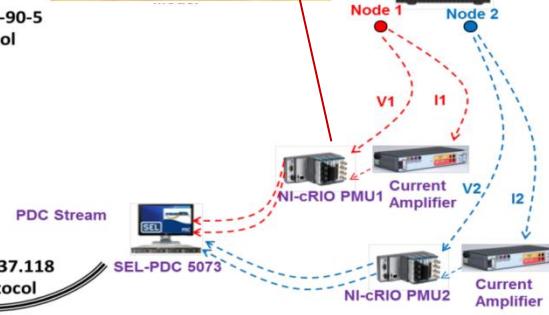
```



National Instrument CompactRIO → PMU



Grid model is simulated in real-time



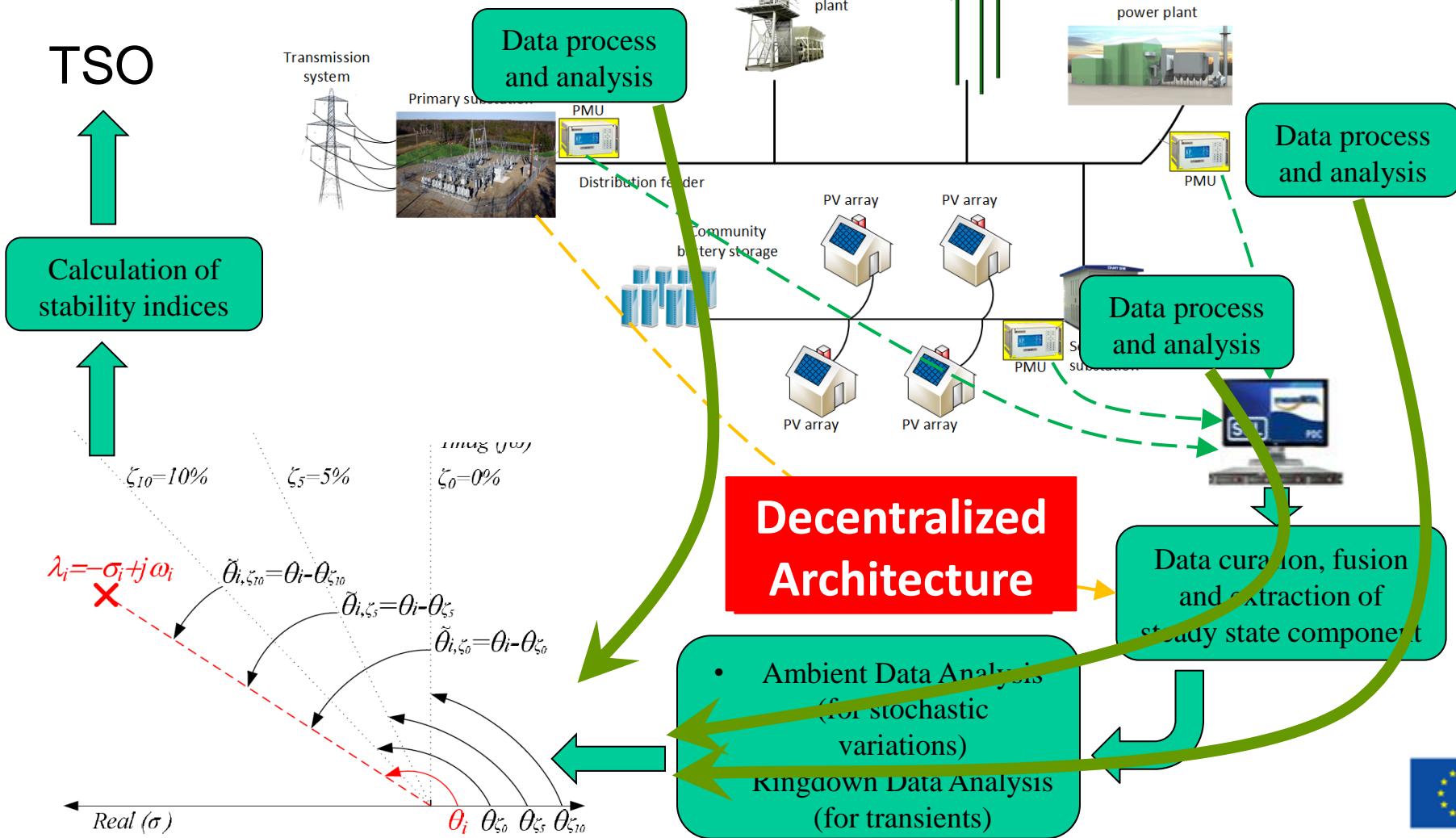
Applications

Providing Dynamic Information



Dynamic Model Synthesis of Distribution System

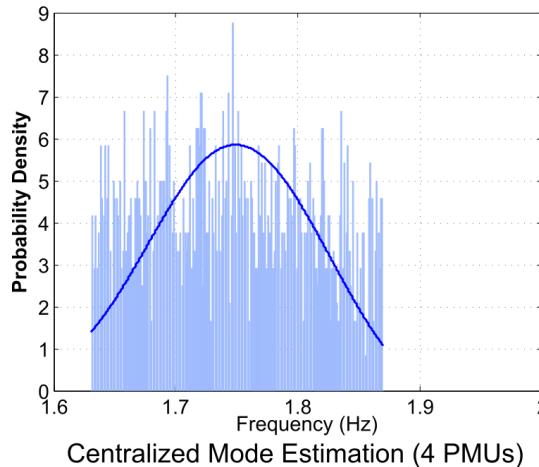
TSO



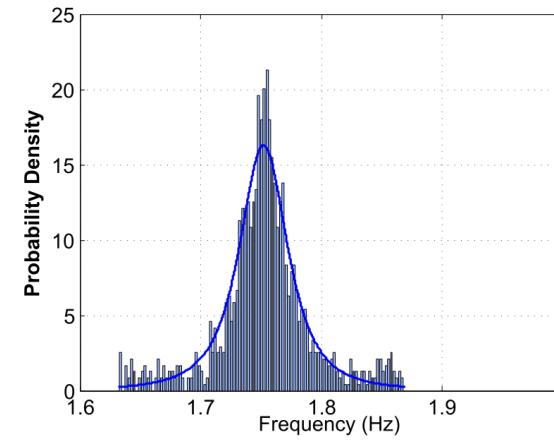
Centralized vs decentralized architecture (better observability)

Decentralized Mode Estimation

Better observability of local modes by using Decentralized Mode Estimation Architecture!

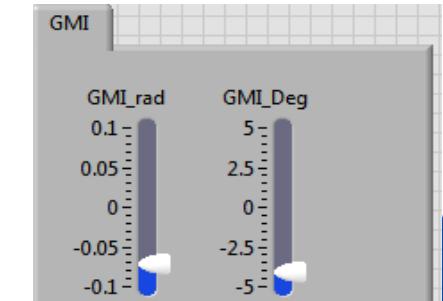
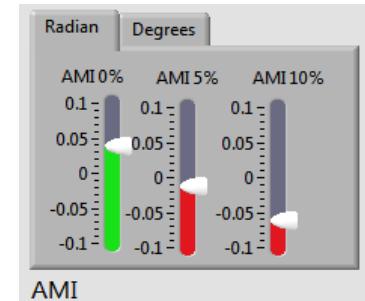
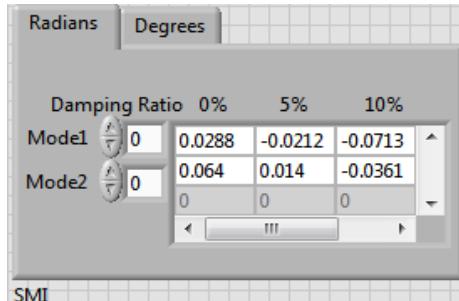


Centralized Mode Estimation (4 PMUs)

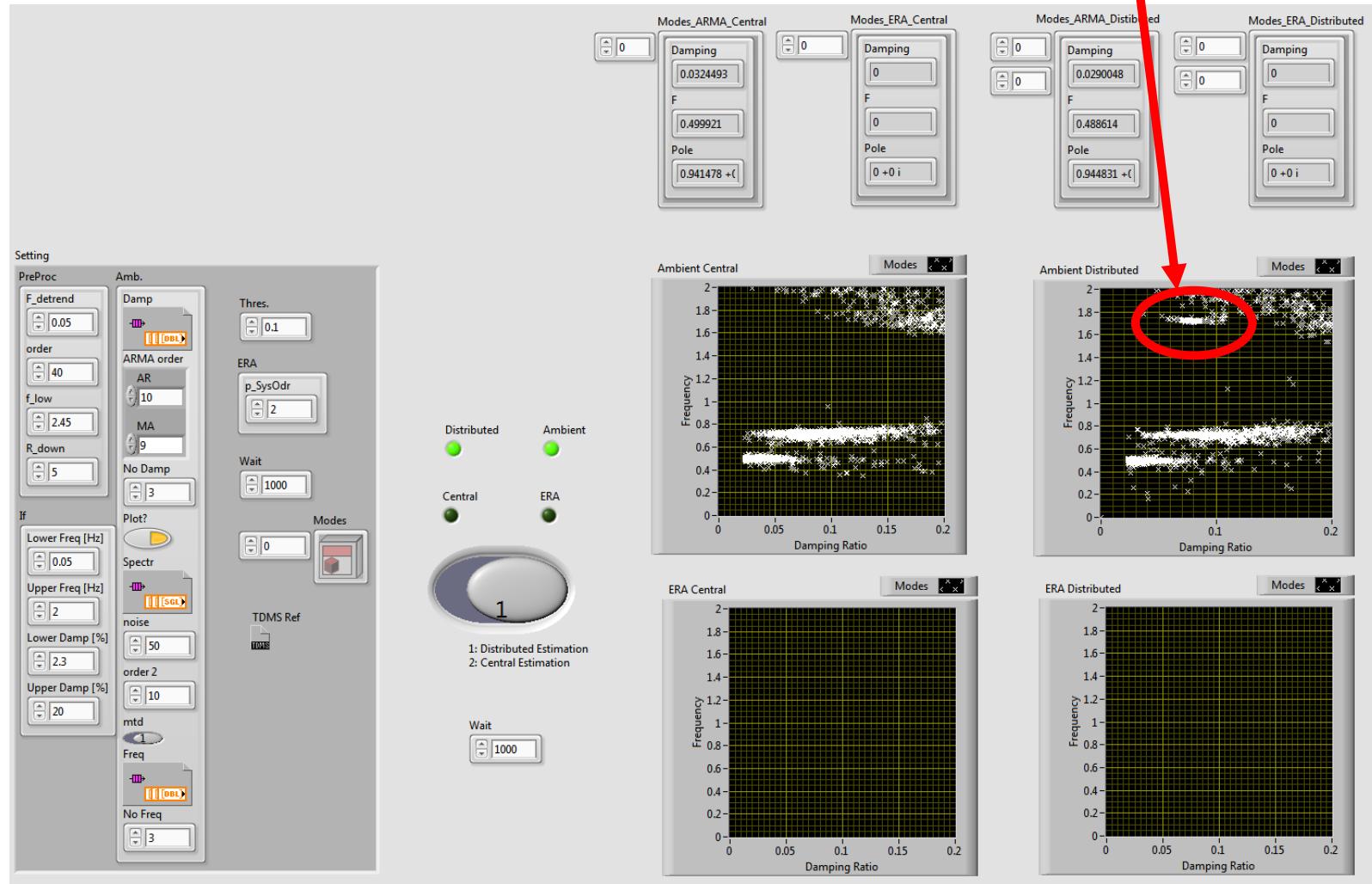


Decentralized Mode Estimation (PMU ID: 4)

Dynamic Stability Indices

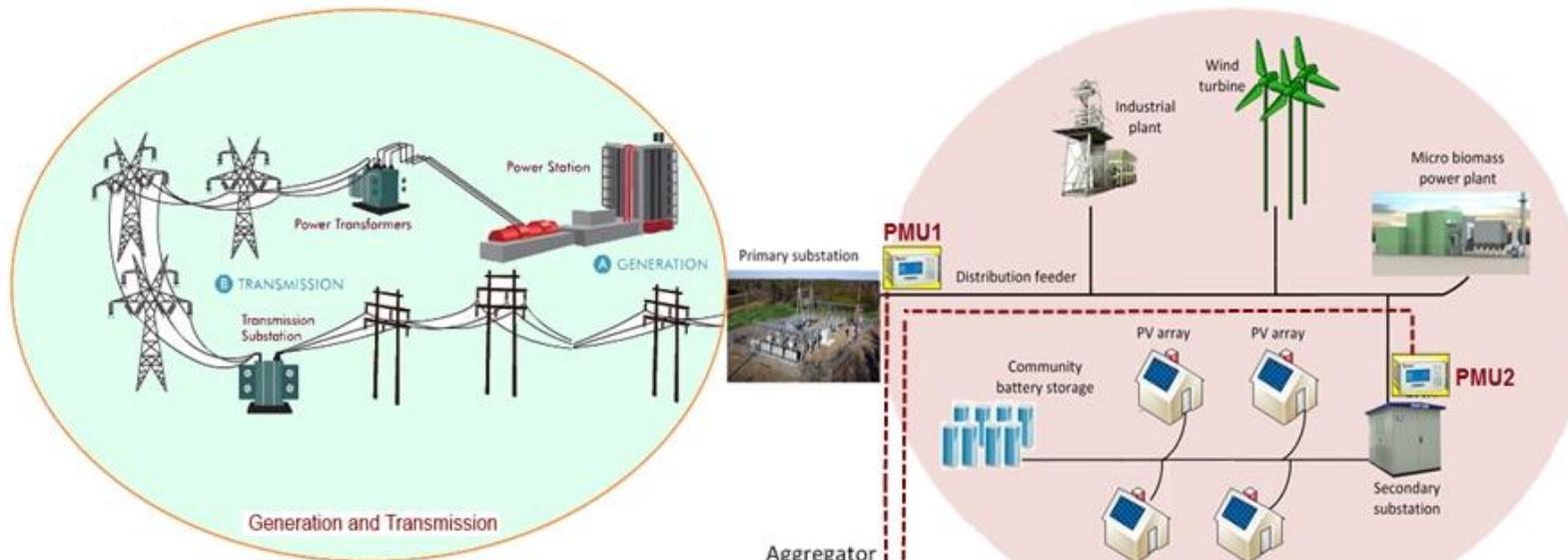


Centralized vs decentralized architecture (local mode visibility)



Voltage Stability Analysis in Distribution Networks

Computation of stability indicators based on real-time measurements and equivalent models.

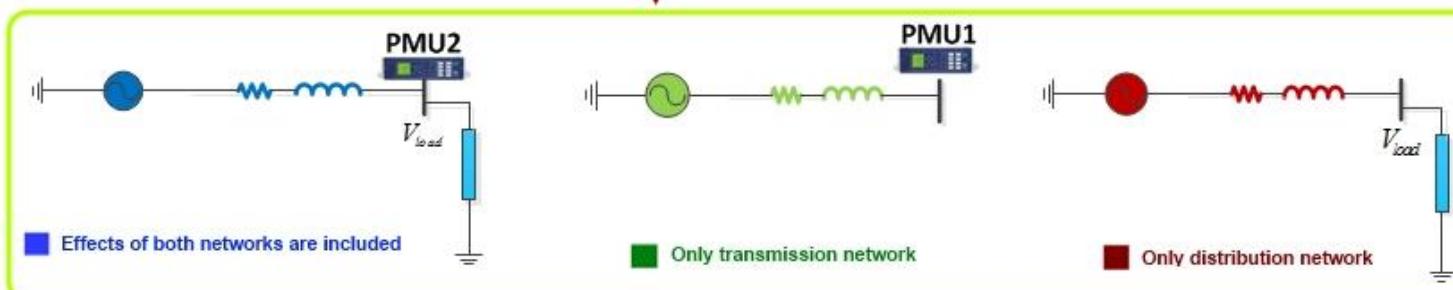


By samplings from PMU1 and PMU2, three different equivalent models are developed

Aggregator

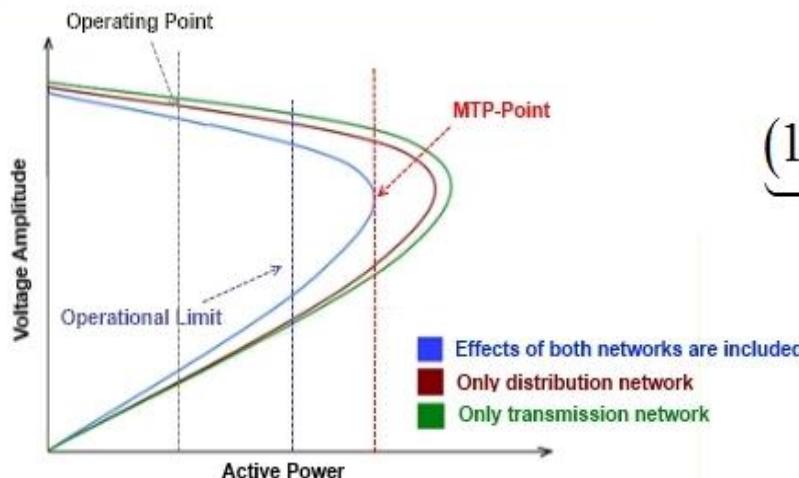
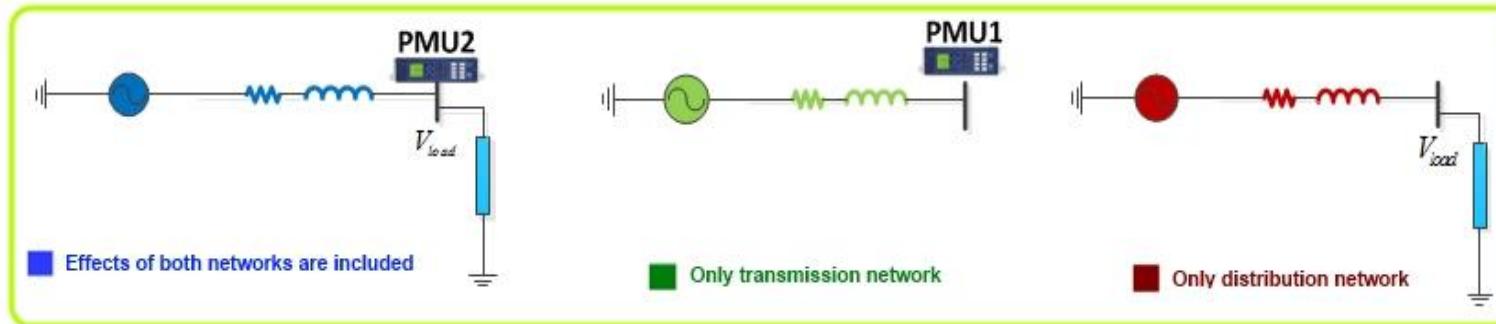
P, Q, and V

Distribution



Three different PV curves are calculated from the three models.

The voltage stability and instability indices are calculated from these models to indicate the contributions of two networks on the voltage stability.



$$(1 - VSI_{total}) = \frac{VSI_{total}}{VSI_{dist.}} + \frac{VSI_{trans.}}{VSI_{trans.}}$$

$$VSI = \text{Voltage Stability Index}$$

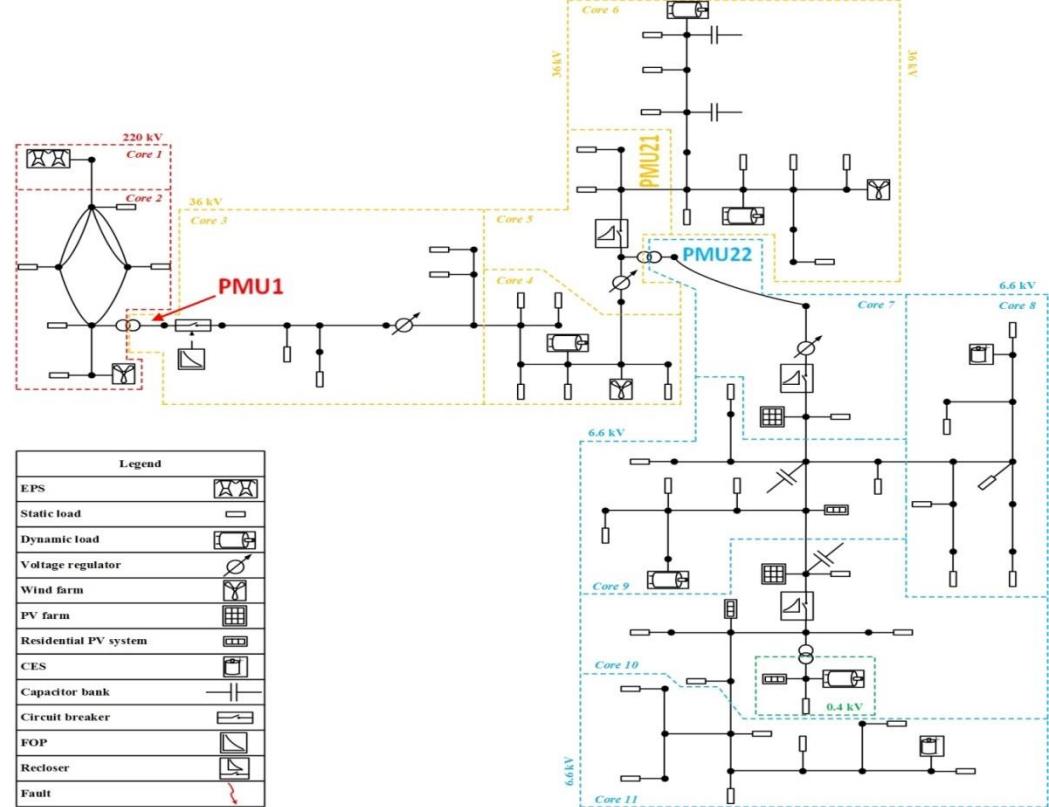
$$VSI = \text{Voltage Instability Index}$$



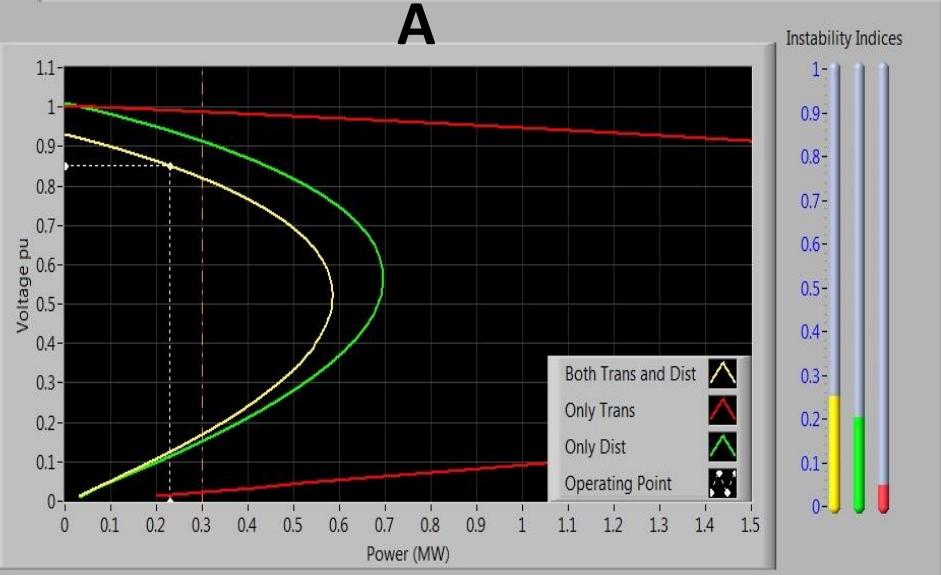
LABVIEW Application

Real-time simulations results for aggregated load (LV network) seen from PMU22:

- A. all distributed generations inside MV network are disconnected
- B. all distributed generations inside MV network are connected



A



B

