Utilizing Smart Inverter Virtual-Sensor Nodes for Enhanced Behind-the-Meter Visibility in High PV Penetration Distribution Feeders

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**Motivation**
Reducing costs by leveraging pre-deployed hardware

**Experimentation**
Validating concepts in RTDS and typhoon HIL

**Conclusion**
Demonstrated viable communications on platforms

**Future Work**
Migrating platform commercial components in future efforts
**Motivation**

Growth of Behind-The-Meter (BTM) Renewable Energy Sources (RES) at the grid edge

- Reconfiguration of Traditional Grid Practices
- Policy Changes
- Infrastructure Upgrade
- Market Redesign

Full visibility of BTM RES
Motivation

Granular visibility into BTM RES

Data Standards & Quality

Stake Holder Obstacles

DOE in 2020 - Award amount: $6 million
Supporting projects that provide utilities better data about rooftop solar power generation

BTM Monitoring & Forecasting

Weather Sensing & Forecasting
**Objective of the project**

Design of low-cost, scalable, multi-functional sensor packages for Enhanced Behind-the-Meter visibility to maximize the ancillary grid services of renewables

**Impact**

Utilizing the increased BTM visibility to:
- Implement customized VV & VW control algorithms for each DER zone
- Controlling all the BTM RES collectively as grid assets to further grid reliability and resiliency
- Reduce operation cost,
- Increase PV hosting capacity

**Virtual Sensor Node**

- Utilizing existing data of distributed inverters controllers as virtual sensing nodes with no additional hardware cost
- Cost-efficient & Reliable communication and coordination among distributed inverters
Fig. 1 Power-Hardware-In-the Loop (PHIL) testbed for connecting Enphase microinverters to RTDS
The actual PV power vs the recorded power

The error of the actual PV power vs. the recorded one every 10 mins
The error of the actual PV power vs. the recorded one every 3 mins
• The implemented wireless communication platform in a PHIL testbed to collect the BTM data (P, Q, V) of the PV inverter and send it to a virtual data aggregator as a web interface
• The testbed is used for clarifying both BTM and dispatch operation data and communication requirement

Wireless Communication platform for a PHIL testbed
The DER controller data will be sent to the Beagle Bone Black via SunSpec Modbus protocol. The BBB acts as a web server and the data could be written on or read from.
IMPACT

- The DER controller data could be monitored on the designed web interface with a fixed IP address.

- The polling data frequency is selectable on the web interface.

- Freedom in choosing the rate of polling data will result in enhanced BTM visibility.

- Data could be downloaded as a .csv file for further analysis.

Web-interface for monitoring the DER data
IMPACT

- Analysis of communication delay between each stage of the testbed
- Maximum total delay from sender to receiver = 2 seconds

Communication latency of various parts of the communication platform

\[ T_{\text{Web-Poll}} \approx 500 \text{ ms} - 1000 \text{ ms} \]
\[ T_{\text{SunSpec-Poll}} \approx 500 \text{ ms} - 1000 \text{ ms} \]
\[ T_{\text{ISR}} \approx 1 \text{ ms} - 5 \text{ ms} \]
IMPACT

- Extension of the communication platform for three Typhoon HIL devices.
- Every typhoon HIL device for real-time simulation of a different DER.
- Aggregation of data from all DERs on the BBB
- Monitoring and remote supervisory control of the system by the web-interface.

a. Three THIL of the testbed  
b. The optical isolator and adaptor for RS-232 to RS-485  
c. The BBB and the network switch
The proposed communication network for collecting BTM DER data and monitor it on a microPMU as a data aggregator.

Collecting each inverter’s data using the LORA modules and the analog inputs of the microPMU.
EXPERIMENTAL TESTBED

Fig. 1 Block diagram of the simulated PV system in Typhoon HIL

Fig. 2a. LORA module 1 & THIL at node 1
Fig. 2b. LORA module 2 & THIL at node 2
Fig. 2c. LORA module 3, raspberry pi, and μPMU at the coordinator node
Fig. 3. Typhoon SCADA data measurement and monitoring at node1.

Fig. 4. µPMU data monitoring at node1

*The installed PV capacity = 15kW at 1000W/m² solar irradiation and 20°C.

*Node 1: solar irradiation= 500W/m² & P = 7.5kW
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<thead>
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<th>Node 1</th>
<th>µPMU</th>
<th>THIL</th>
<th>Error%</th>
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<tr>
<td>V(V)</td>
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<td>P(kW)</td>
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<td>F(Hz)</td>
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Fig. 3. Typhoon SCADA data measurement and monitoring at node1.

Fig. 4. µPMU data monitoring at node1.
Fig. 5. Typhoon SCADA data measurement and monitoring at node2.

Fig. 6. µPMU data monitoring at node2

*The installed PV capacity = 15kW at 1000W/m² solar irradiation and 20°C.

*Node 2: solar irradiation= 1000W/m² & P = 15kW
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<td>P(kW)</td>
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<td>F(Hz)</td>
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Fig. 5. Typhoon SCADA data measurement and monitoring at node2.  
Fig. 6. µPMU data monitoring at node2
**FUTURE PLAN**

- Using Commercial microinverters for validating the virtual sensor concept
- Implementing a virtual data aggregator and data management platform to collect the BTM sources data
- Utilizing the increased BTM visibility to implement customized VV & VW control algorithms for each DER zone