U.S. DEPARTMENT of ENERGY | Office of Critical Minerals and Energy Innovation

DASH-IBR: Dynamic Assessment of System Health for IBR-dominant Power Systems

OPTIMA Award # DE-EE0011372

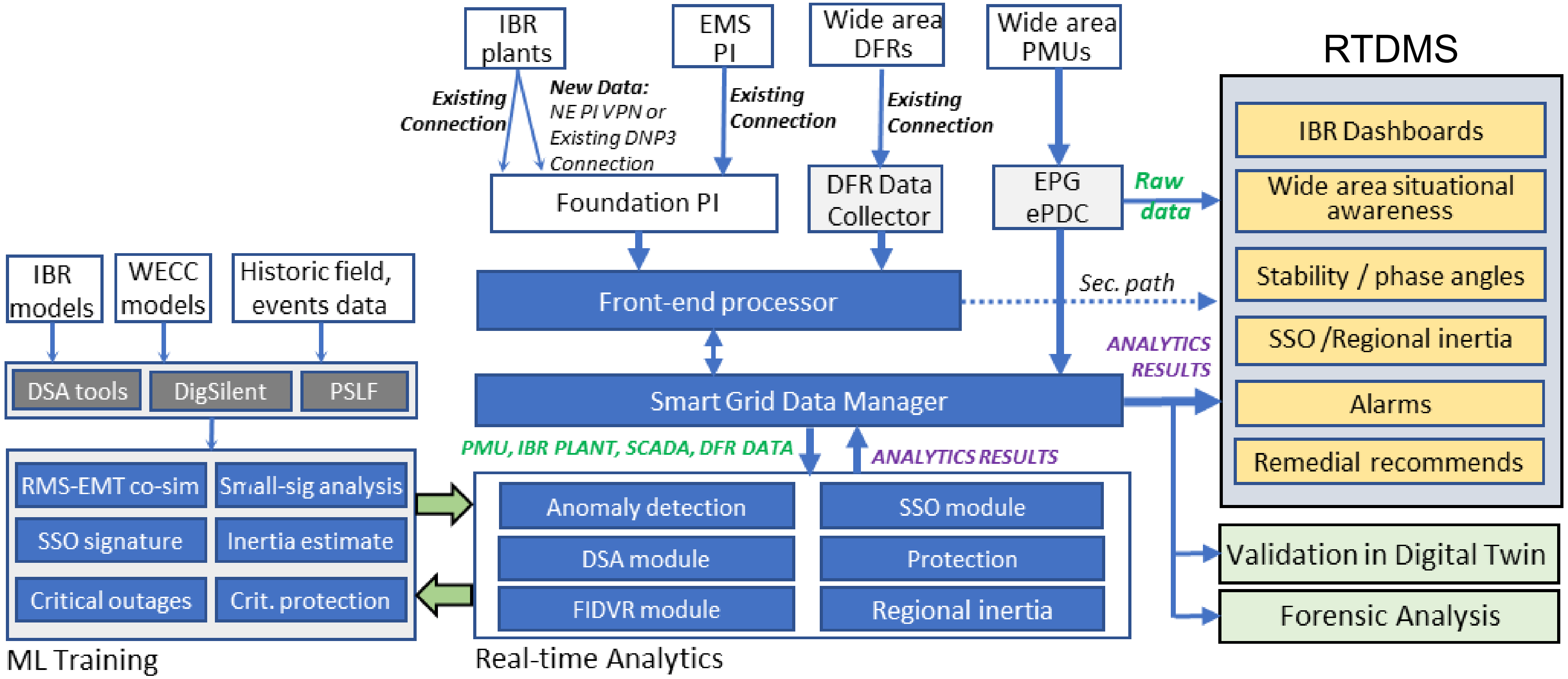
Project Partners:

Arizona State University (ASU)
Salt River Project (SRP)
Electric Power Group (EPG)
California ISO (Advisory role)

Proposed Technology, Real-time Data streams, and Operator Visualization

Five analytical modules of DASH-IBR: Dynamic Assessment of System Health for IBR dominant power systems

- **DSA Tool**
- **SSO Analytics**
- **Regional Inertia**
- **Anomaly Detection**
- **Cascade Mitigation**



Validated EMT, RMS and Real-time (Digital Twin) Models for IBRs/Plants (led by Raja Ayyanar)

- Detailed IBR (unit/plant) EMT models accurately capturing **IBR control** and **fault responses** are critical
- Given the large BPS under study (entire WECC), an **EMT-RMS co-simulation** is essential

Modeling inputs

- IBR OEM black box EMT models
- Commissioning test results
- IBR plant design, collector systems
- Standards, interconnection docs
- Prior modeling and control efforts
- System/operator settings, practices
- Field measurements – PMU, DFR, plant SCADA, steadystate/events

Model development process

- Time domain, freq. domain, impulse excitations on OEM blackbox models
- Control tuning, PLL tuning and mapping
- Model validation with field measurements and across multiple EMT platforms
- Continuous, closed loop model refinement
- Derivation of RMS models capturing critical characteristics and validation with EMT

Main outputs

- EMT models with validated controls
- DigSilent EMT and RMS IBR models suitable for co-simulation
- Real-time models for digital twin
- Critical transfer functions for stability studies, control commands
- GFL/GFM fault, VRT, FRT responses
- Correspondence between settings and IBR dynamic responses

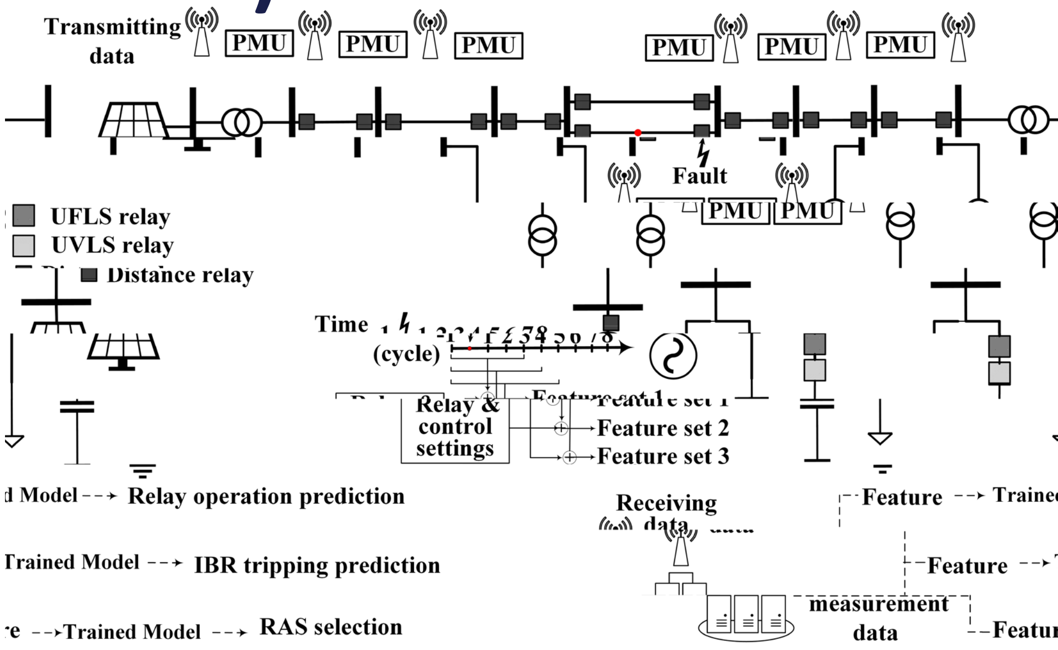
- Build on ASU's ongoing work with SRP in developing such models starting from OEM Blackbox models, and new IBR plant design data
- Mapping of control settings to specific responses such as **momentary cessation**, **oscillations**

Team's collective expertise in power electronics, power systems and controls

Continuous model refinement using field data including from DFRs

Dynamic Security Assessment (DSA) for IBR-dominated Power Systems (led by Mojdeh Khorsand)

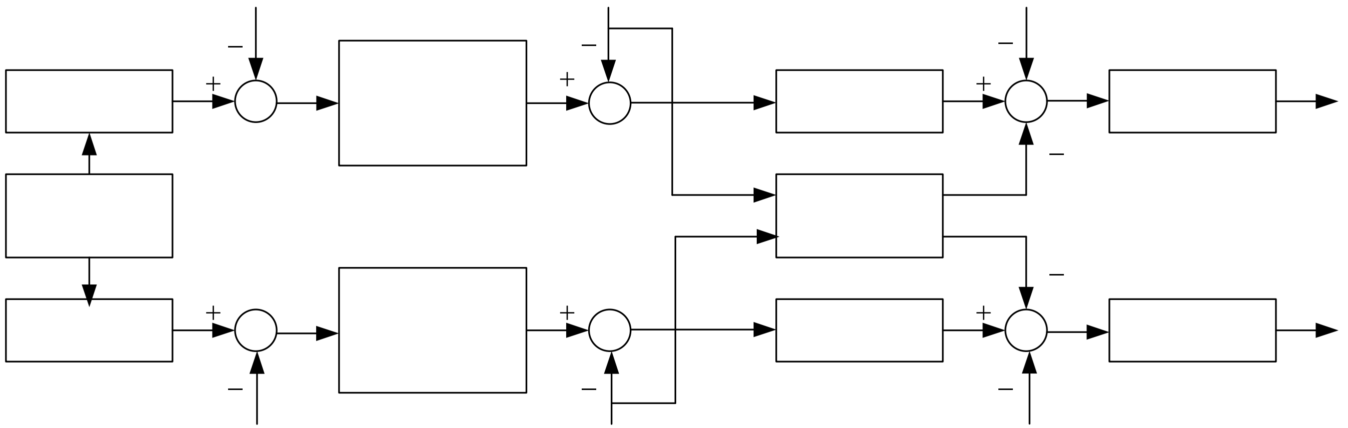
- **Objective:** Design, develop, and demonstrate a DSA tool
  - **Faster** than real-time assessment
  - **Identification** of areas with potential inverter tripping and protection operation/mis-operation
  - Analysis and **visualization** of extent of plausible disturbances: consecutive outages due to protection and control interactions
  - **Causal AI-based approach** to enhance accuracy and speed of DSA and decision-support for remedial action scheme selection
  - Training AI-based tool using RMS-EMT-Protection co-simulation results
  - Testing using WECC data



Visualization to the operators

Sub-synchronous Oscillation (SSO) Detection and Mitigation (led by Vijay Vittal)

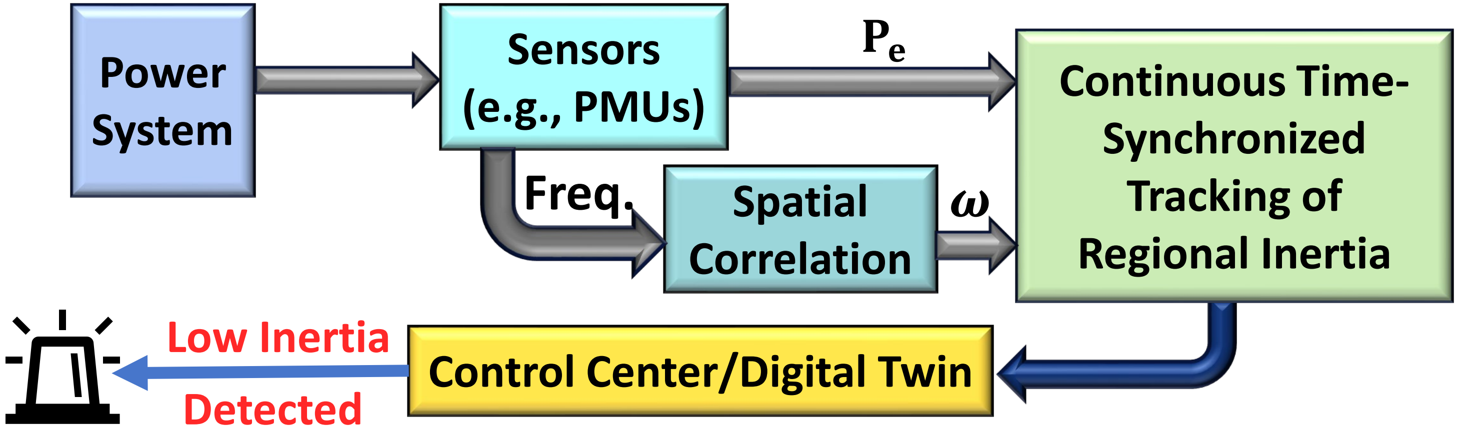
- Impedance/Admittance methods effective methods to **detect** SSOs
- In an operations setting such methods are **computationally burdensome**
- **Adaptation:** 30 to 50-minute look-ahead operating horizon – **combine** offline analysis at relevant SSO frequencies with **PMU and POW measurements** and EMS data to **determine** operating conditions and events **likely to cause SSOs**
- When such conditions are detected, **use impedance/admittance** analysis at identified frequencies to **detect possibility of SSOs**



- Take **preventive/corrective** control to mitigate SSOs
- Preventive: **adjust generation** as needed to meet load and change operating condition – would necessitate operating with some head room at IBRs
- Corrective: utilize a suitably designed **damping controller** – impedance/admittance analysis with measurements – detect SSO then POW measurement used to trigger damping control

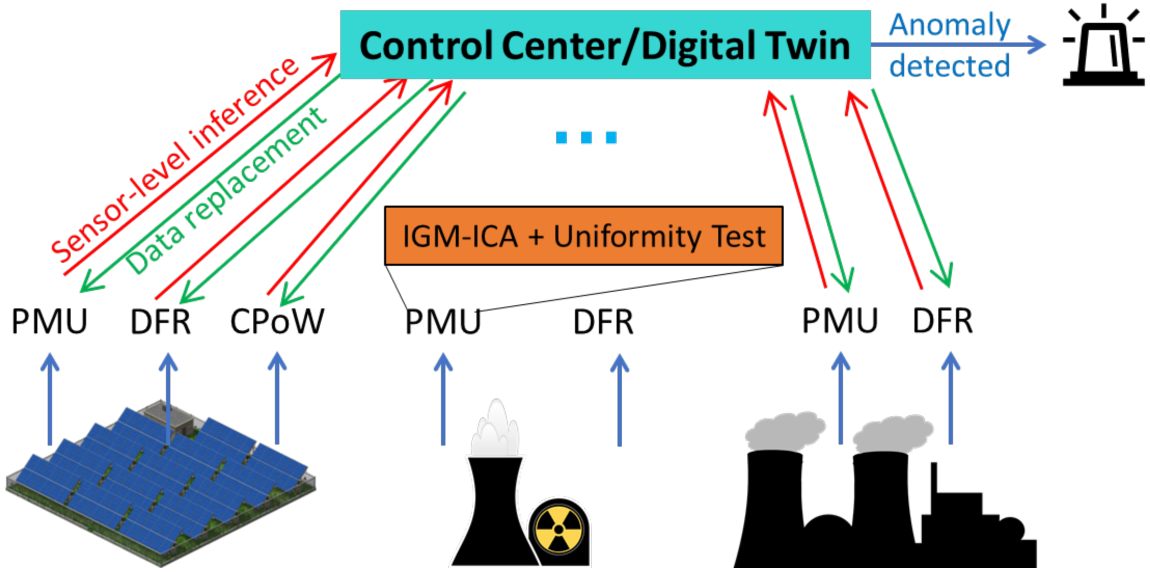
Continuous Time-Synchronized Tracking of Regional Inertia (led by Anamitra Pal)

- **Goal:** Track regional inertia using **ambient data** from select PMUs without assuming mechanical power input to be a known constant



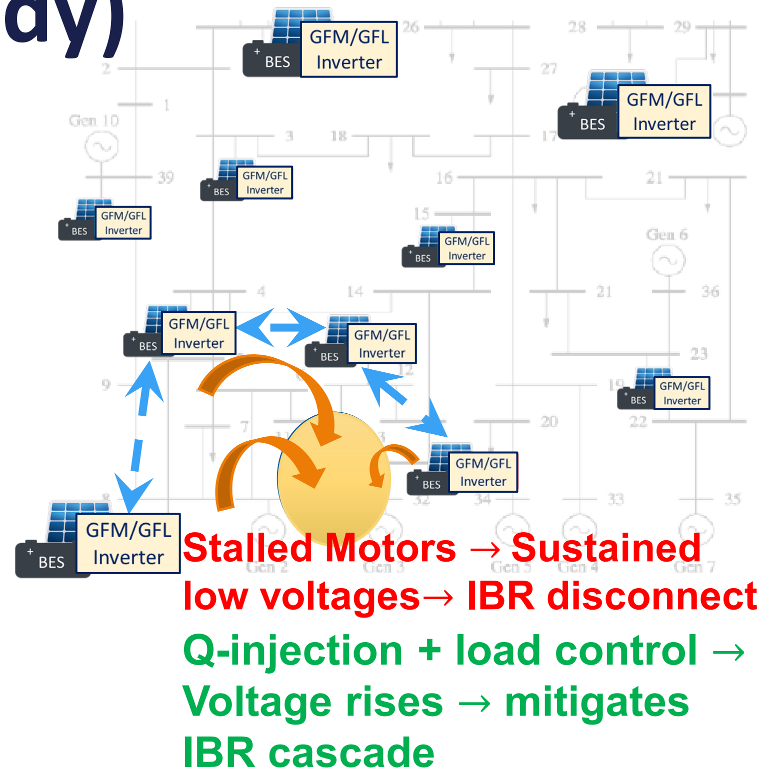
- **Approach:** Compute inertia from the **small variations in PMU-measured power and frequency** that occur under ambient conditions, and which reflect the system's electrical and kinetic energy fluctuations
  - **Frequency spatial correlations** are exploited to overcome lack of PMU coverage
  - A partitioned form of the swing equation is used to **identify changes in mechanical power inputs** and update inertia estimates
- **Innovation:** Continuously track regional inertia (i.e., **not rely on occurrence of events**)
  - Relaxation of the need for redundant observability by PMUs
  - Relaxation of the assumption of constant mechanical power input

High-Speed Anomaly Detection and Response in IBR-rich Power Systems (led by Anamitra Pal)



- **Goal:** Detect anomalies in streaming high-speed sensor data by **learning correlations** from historical non-anomalous data
- **Approach: Non-parametric anomaly sequence detection** to differentiate faulty sensors from IBR/grid anomalies
  - Combine **generative AI** with uniformity testing for sensor-level anomaly detection
  - Combine inferences from sensor-level detectors for system-level anomaly detection
- **Innovation:** Circumvents the **labor-intensive task** of creating different types of synthetic anomalous data and/or labeling anomalies in archived data
  - Overcomes problem of **unknown statistical dependencies** in streaming sensor data
  - **Fast response mechanism** tailored to the type of anomaly identified

Mitigation of FIDVR and IBR Cascades via Distributed Corrective Control (led by Amarsagar Reddy)

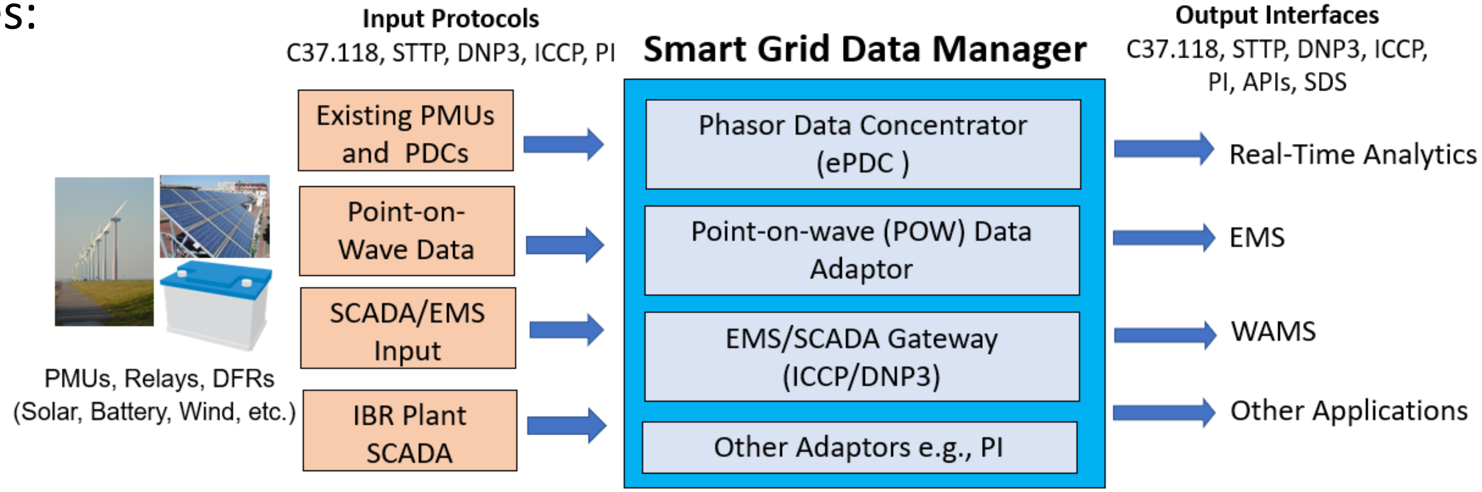


- **Goal:** Localize, quantify and mitigate the IBR cascade risk due to FIDVR in real-time to prevent voltage instability
- **Approach:** IBR Q-Injection and load control in region with FIDVR using streaming measurements
  - **Localize/Quantify FIDVR** based on the admittance variation (>95% accuracy within 2 sec. of fault)
  - **Local/Distributed control** formulated as a model predictive control problem and solved via offline learning
- **Innovation:** Local + distributed methods reduce latency to track system voltage stability and **mitigate IBR cascades that cause widespread PV output disruption**
  - **Model predictive control** formulation focusing on proximal resources
  - Exploits dispersed IBRs to mimic a **"movable" SVC/STATCOM**

SGDM: Integrate Data from Multiple Sources for Real-Time Analytics (led by EPG)

- Leverage EPG's *e*PDC to design and develop SGDM
- Handle data streams from multiple sources:
  - PMUs
  - POW
  - EMS/SCADA
  - DFRs (offline data + real-time stream)
  - IBR plant SCADA
- EPG developing data adaptors and interfaces for integration with data sources, ASU algorithms/analytics and other 3rd Party systems
- Integration with EPG's RTDMS platform for visualization of results

Smart Grid Data Manager: Platform for integrating multiple data sources to real-time analytics and applications



EPG's RTDMS Platform

Functional & Design Specifications for SGDM Completed; Software Development and Analytics Integration ongoing

Thank you!