2017 ADMS Program
Steering Committee Meeting

Advanced Intelligent Sensor Development and Demonstration for Future Distribution Systems with High Penetration DERs

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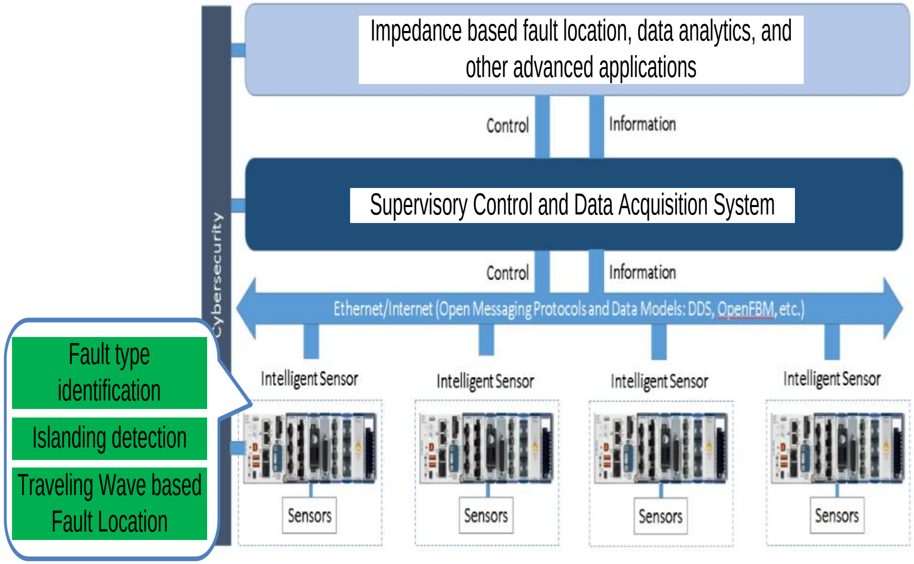
Advanced Intelligent Sensor Development and Demonstration for Future Distribution Systems with High Penetration DERs

Objectives & Outcomes

To develop, laboratory test, and field demonstrate sensors and software that permit voltage, current and impedance to be measured in a customer-sparse distribution system with significant installed solar and wind power.

Minimum outcome: Cost of fault location in rural electric cooperatives will be reduced significantly



Technical Scope

1. Develop and bench test new sensor hardware and software
2. Develop fault location software
3. Do control hardware-in-the-loop testing of the sensors and fault location software in UT's 1 MW microgrid and an Opal RT simulator
4. Assess performance in limited duration field tests of hardware an software
5. Demonstrate full system performance in a electric rural cooperative.

Life-cycle Funding Summary

FY18, authorized	FY19, planned	FY20, planned
$10k	$733k	$668k

Needs Addressed

- Key need
  - Better situational awareness in distribution systems
- Focus is on distribution systems that
  - Serve larger geographic areas
  - Have distributed energy resources (DERs)
- Situational awareness addressed via intelligent sensors and models to permit
  - Fault-type identification
  - Fault location
  - Islanding detection
  - Optimal sensor placement

Operational Challenges Addressed

- Distribution systems not historically monitored
  - Situation is changing
  - Challenge for rural electric cooperatives
    - Even if it is known that an outage is between two customers that could be a distance of 20+ miles
    - ~900 cooperatives in 47 states
    - Deliver 11% of the energy sold in US
    - Maintain 42% of distribution lines
    - Average about 7 customers/mile of line
      - Investor owned utilities almost 35 customers/mile

  - This technology
    - Affordable solution
    - Addresses fault location first
    - Supports additional distribution automation as it becomes important

Project Significance

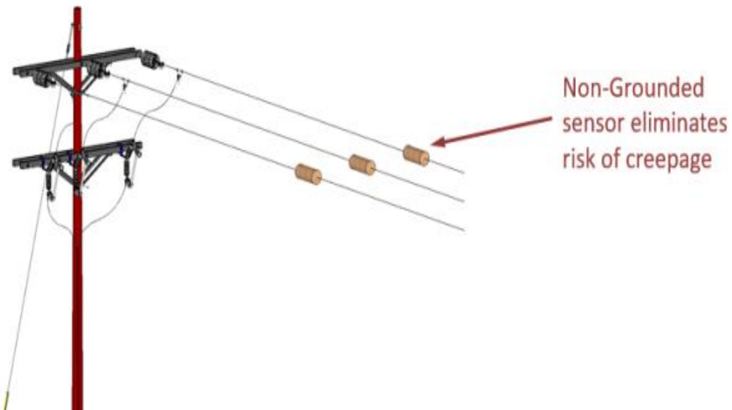
- Reduces cost of fault location
  - Low cost sensors and software
  - Replaces staff time searching for fault
- Fault characterization
  - Can reduce repair time
- Provides experience and infrastructure for future distribution automation

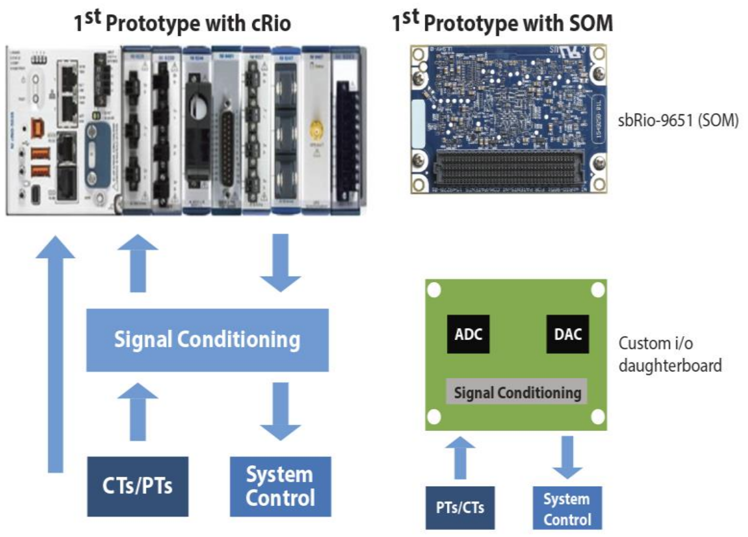
Project Approach

- Develop smart sensors
  - Data-to-information
  - No new ground connection
    - Reduces safety concerns
- Develop fault location and identification software
- Hardware-in-the-loop tests using UT’s 1 MW microgrid and real time simulator
- Testing in distribution system to identify installation, safety or reliability problems to be fixed
- System demonstration in distribution system

Smart Sensors

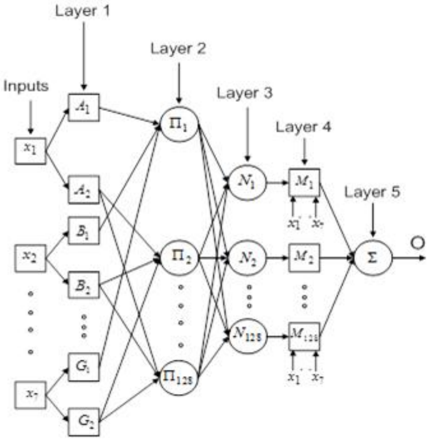
- Sense electric and magnetic fields
  - Calculate voltage and current
  - Calculate impedance
  - Fault identification
- Synchrophasor-based islanding detection method will be developed and embedded in the intelligent sensors





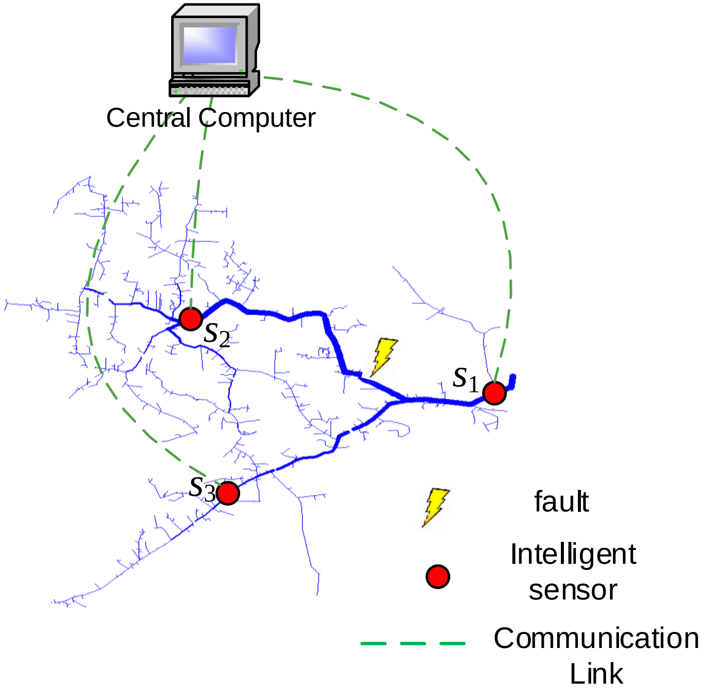
Fault Management Software

- Important primary attributes
  - Fault type identification
    - Data driven, signal processing, and machine-learning-based fault-type identification
      - Distinguishes between a transient and permanent fault using wavelet analysis a neuro-fuzzy network will be designed to determine the nature of the fault.
      - Decision on fault type can be made within five power cycles after a fault.
  - Fault location
    - Phasor-based method.
      - Sampling rate of 2 kHz for voltage/current sensors is sufficient
        - Accuracy should increase at higher rates
      - Computation time
        - Less than second



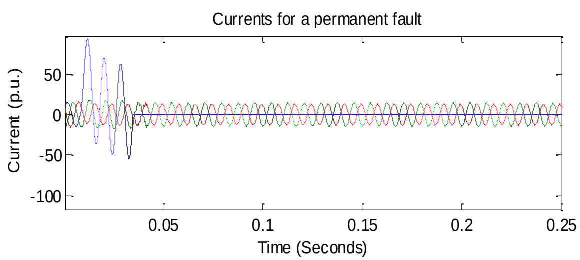
Centralized Impedance Model-Based Fault Location

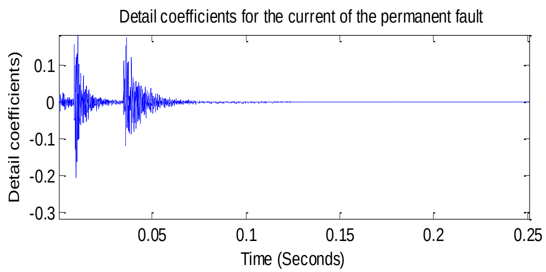
- A centralized bus impedance matrix based fault location method
- Advantages
  - Applicable to meshed networks integrated with distributed generations
  - Accurately pinpoint fault location within the faulted segment
  - Computationally efficient analytical formulation (without iterations)
  - Uses multiple records obtained from any bus in the network
  - Enables fast service restoration and improve utility SAIDI/SAIFI

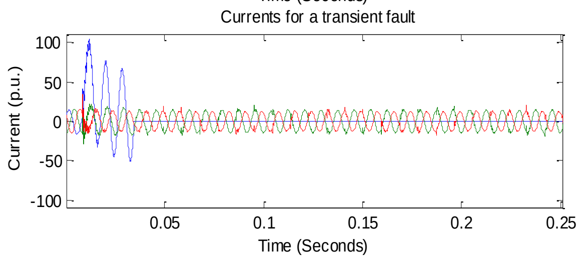


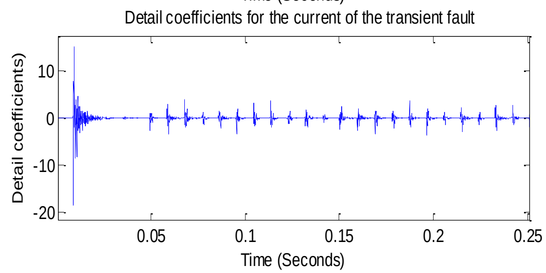
Fault Type (Permanent Vs Transient) Identification

- A data driven, signal processing and machine-learning-based fault-type identification
- Wavelet analysis to extract distinctive features from the
- Neuro-fuzzy network will be designed to determine the nature of the fault
- The algorithm will be implemented in intelligent sensors to drive the opening/close of recloser actuators



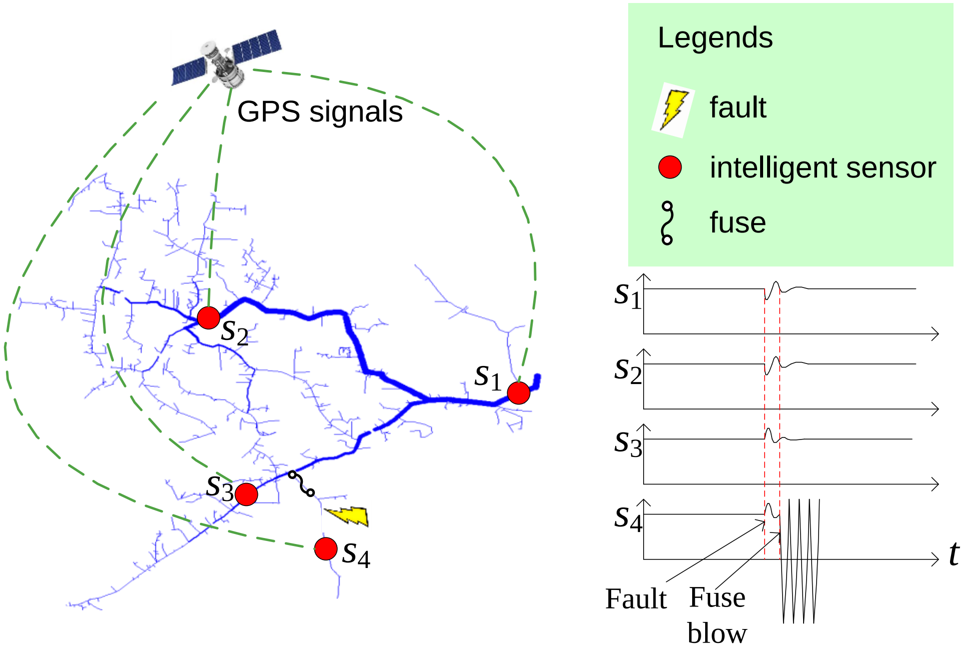






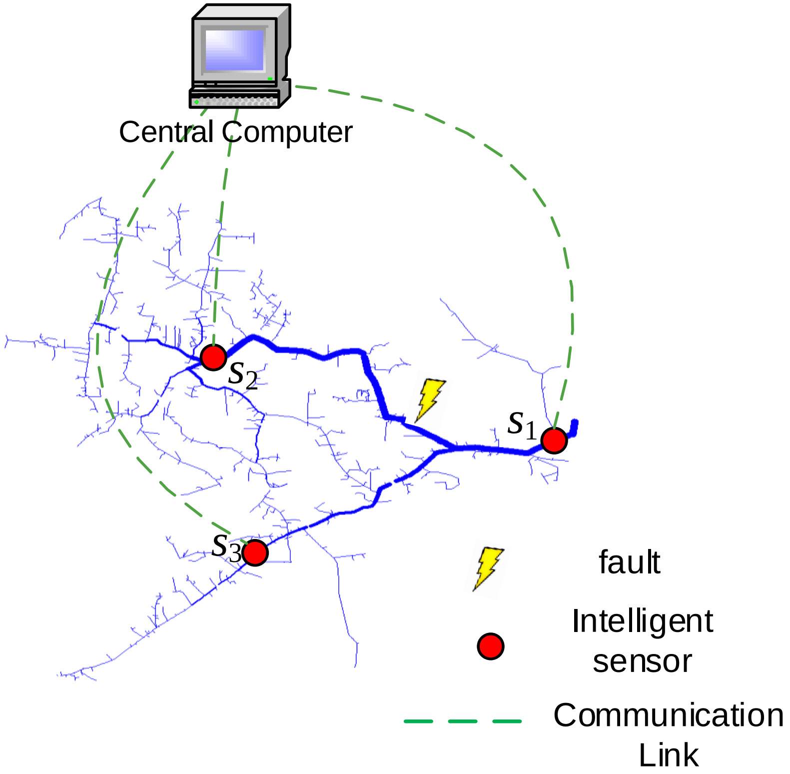
Islanding Detection

- A synchrophasor-based islanding detection method
- Benefit
  - Recognize islanding condition and disconnect the DER from legacy grid
  - Keep the DER connected and ride-through disturbances originating in the transmission grid or adjacent feeders



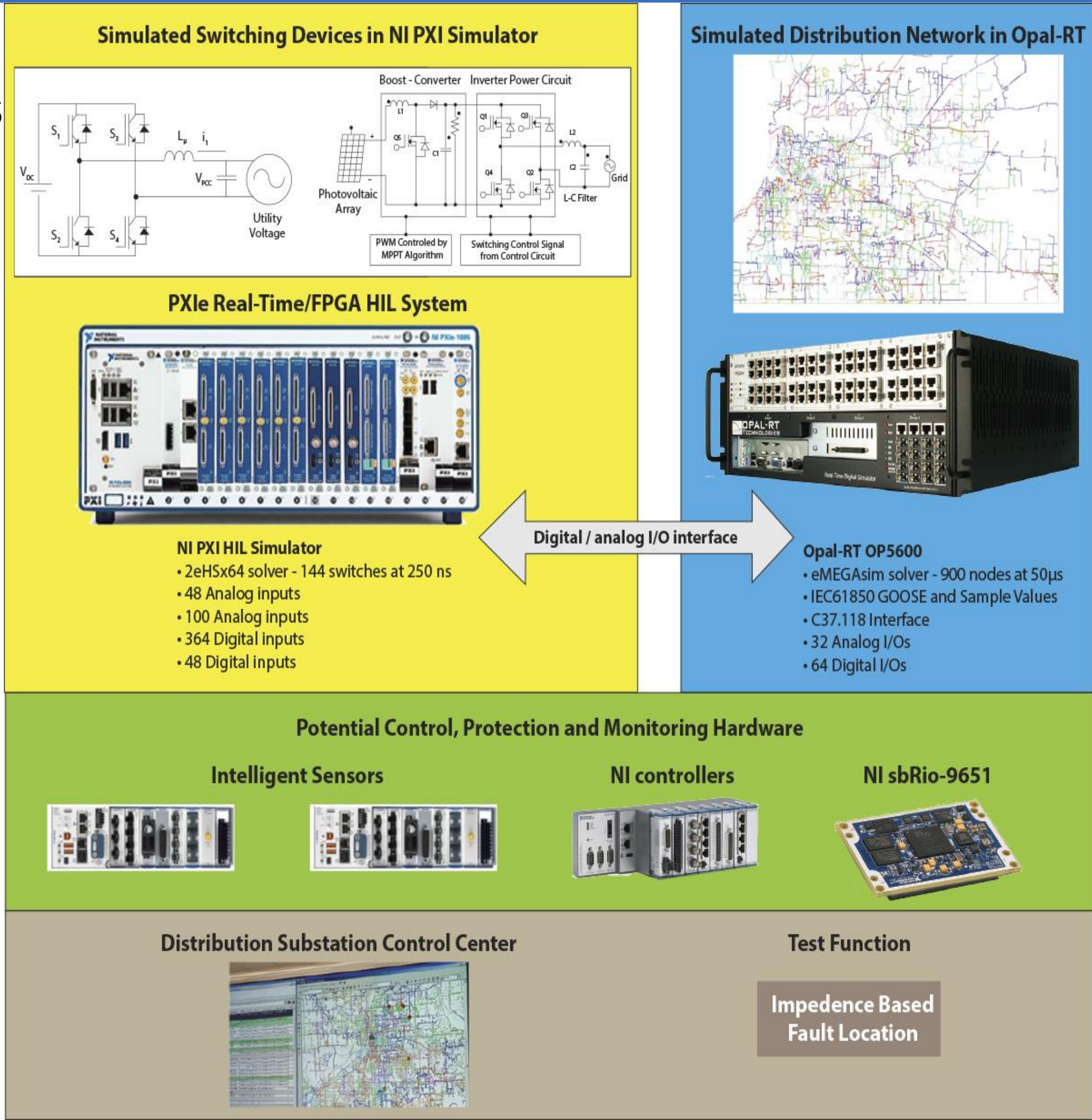
Traveling Wave Based Fault Location

- Challenges
  - Energy useful for traveling wave based fault locating is mostly present in 20 kHz to 2 MHz range
    - Need fast communication and synchronization
- Requirement
  - GPS synchronization
  - High sampling rate sensors
  - Fast processing speed
- Benefit
  - Incipient fault location (sub-cycle fault)
  - Simple algorithm



Hardware-in-the-Loop Testing

- Simulate distribution network with high penetration of DERs in real time
  - Opal-RT and NI FPGA simulator
- Test intelligent sensors in the real-time control-HIL environment
  - Test applications on intelligent sensors
    - Fault type identification
    - Islanding detection
    - Traveling wave based fault location
  - Test application on central computer
    - Impedance based fault location



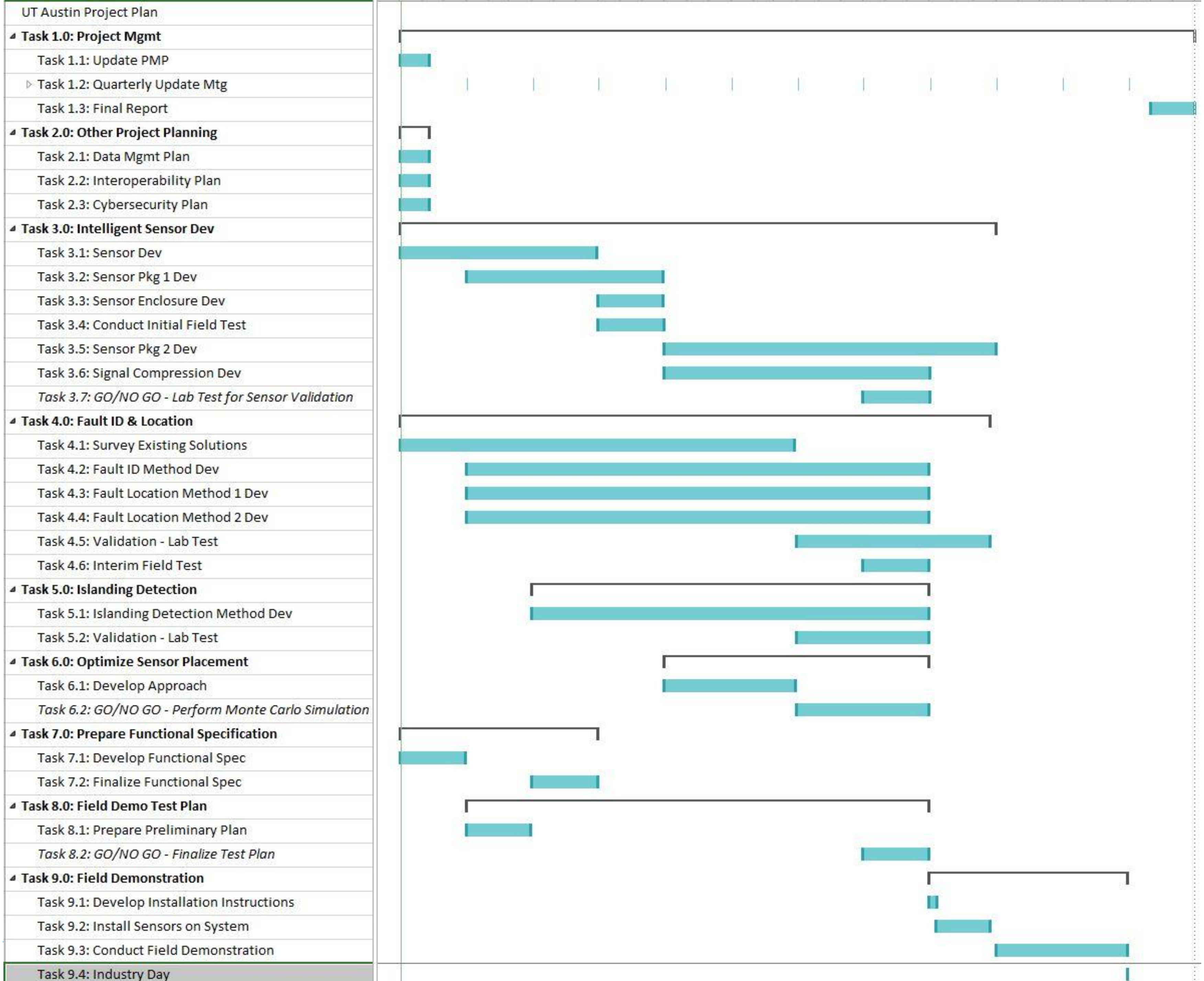
Test and Demonstration in Operating Power System

- Throughout the project, sensors will be installed in a operating system to identify
  - Unanticipated installation challenges
  - Reliability issues that were not identified in testing
- In year three, a demonstration of the entire system will be done with our coop partner

Key Risks

- Risk 1 – Sensor Performance
  - Mitigation
    - Early in program
    - Experienced team support

- Risk 2 – Utility Integration
  - Mitigation
    - Hardware-in-the-loop testing
    - Multiple component tests in grid prior to demonstration


UT Austin Project Plan
Task 1.0: Project Mgmt
Task 1.1: Update PMP
Task 1.2: Quarterly Update Mtg
Task 1.3: Final Report
Task 2.0: Other Project Planning
Task 2.1: Data Mgmt Plan
Task 2.2: Interoperability Plan
Task 2.3: Cybersecurity Plan
Task 3.0: Intelligent Sensor Dev
Task 3.1: Sensor Dev
Task 3.2: Sensor Pkg 1 Dev
Task 3.3: Sensor Enclosure Dev
Task 3.4: Conduct Initial Field Test
Task 3.5: Sensor Pkg 2 Dev
Task 3.6: Signal Compression Dev
Task 3.7: GO/NO GO - Lab Test for Sensor Validation
Task 4.0: Fault ID & Location
Task 4.1: Survey Existing Solutions
Task 4.2: Fault ID Method Dev
Task 4.3: Fault Location Method 1 Dev
Task 4.4: Fault Location Method 2 Dev
Task 4.5: Validation - Lab Test
Task 4.6: Interim Field Test
Task 5.0: Islanding Detection
Task 5.1: Islanding Detection Method Dev
Task 5.2: Validation - Lab Test
Task 6.0: Optimize Sensor Placement
Task 6.1: Develop Approach
Task 6.2: GO/NO GO - Perform Monte Carlo Simulation
Task 7.0: Prepare Functional Specification
Task 7.1: Develop Functional Spec
Task 7.2: Finalize Functional Spec
Task 8.0: Field Demo Test Plan
Task 8.1: Prepare Preliminary Plan
Task 8.2: GO/NO GO - Finalize Test Plan
Task 9.0: Field Demonstration
Task 9.1: Develop Installation Instructions
Task 9.2: Install Sensors on System
Task 9.3: Conduct Field Demonstration
Task 9.4: Industry Day

Project Team and Budget

Team Member	Role	Total Funding
University of Texas	Program management Fault location algorithms Hardware-in-the-loop testing Demonstration	$1250k
Verivolt	Sensor development	$337k
Argonne National Laboratory	Fault identification algorithms Anti-islanding algorithms Optimal Sensor placement	$320k
Utility	In-system testing Demonstration safety	$170k

Contact

Presenter and PI

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