U.S. DEPARTMENT OF
ENERGY

Infrastructure Security
& Energy Restoration

Prepare. Respond. Adapt.

GMD Monitoring and Mitigation for the Electric Grid

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GMD MONITORING APPROACH: Requirement

NATIONAL SPACE WEATHER ACTION PLAN

4.2 Develop a Real-Time Infrastructure Assessment and Reporting Capability The following actions will enable and increase capacity for real-time monitoring of the electric power system during space-weather events:

4.2.1 DOE, in coordination with DHS, DOC, and stakeholders in the energy sector, will develop plans to provide monitoring and data collection systems. The plans will inform a systemwide, real-time view of geomagnetically induced currents (GICs) at the regional level and, to the extent possible, display the status of power generation, transmission, and distribution systems during geomagnetic storms. Deliverable: Complete plan for national GIC and grid monitoring system and delineate responsibilities for deployment Timeline: Within 1 year of the publication of this Action Plan

4.2.2 DOE, in coordination with regulatory agencies and the electric power industry, will define data requirements that facilitate a centralized reporting system to collect real-time information on the status of the electric power transmission and distribution system during geomagnetic storms. Deliverable: Define data requirements Timeline: Within 1 year of the publication of this Action Plan

GMD MONITORING APPROACH: Benefits

Increases understanding of the specific technical impacts of a GMD event on the grid to better assist the electricity sector in determining ways to mitigate or prevent widespread power outages;

Improves accuracy and reliability of models and modeling parameters, allowing for greater reliability, optimization of operations, and increased resilience against high-impact, low-frequency events;

Provides insights on options for operational plans and mitigation and protection investments

Identifies knowledge gaps related to GMD events

GMD MONITORING APPROACH: Overview

FOUR PARTS to the RECOMMENDED APPROACH

Transformers: Collect individual transformer data on temperature, voltage, and current measurements above what is presently done in control systems for the operation and protection of transformers.

Substations: Outfit substations for additional monitoring of harmonics for predictive capabilities and additional warning indicators specific to GMD.

Regional data collection: Establish regional indicator systems through intensive monitoring of critical transformers and more fully equip them with data-gathering systems focused on GMD monitoring.

Data dissemination: Encourage real-time external distribution of geomagnetic measurements, which can then be incorporated into more accurate and comprehensive nationwide databases.

GMD MONITORING APPROACH: Report

DOE GIC Blocker Pilot Program

EXECUTIVE ORDER

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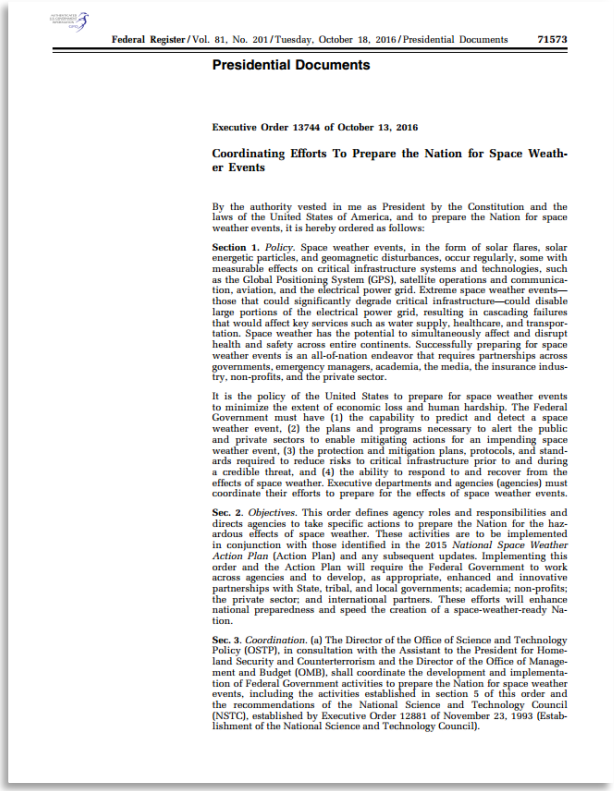
COORDINATING EFFORTS TO PREPARE
THE NATION FOR SPACE WEATHER EVENTS

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows: ...

Sec. 5. Implementation. (a) Within 120 days of the date of this order, the Secretary of Energy, in consultation with the Secretary of Homeland Security, shall develop a plan to test and evaluate available devices that mitigate the effects of geomagnetic disturbances on the electrical power grid through the development of a pilot program that deploys such devices, in situ, in the electrical power grid. After the development of the plan, the Secretary shall implement the plan in collaboration with industry. In taking action pursuant to this subsection, the Secretaries of Energy and Homeland Security shall consult with the Chairman of the Federal Energy Regulatory Commission.

DOE GIC Blocker Pilot Program



Federal Register / Vol. 81, No. 201 / Tuesday, October 18, 2016 / Presidential Documents 71573

Presidential Documents

Executive Order 13744 of October 13, 2016

Coordinating Efforts To Prepare the Nation for Space Weather Events

By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows:

Section 1. *Policy.* Space weather events, in the form of solar flares, solar energetic particles, and geomagnetic disturbances, occur regularly, some with measurable effects on critical infrastructure systems and technologies, such as the Global Positioning System (GPS), satellite operations and communication, aviation, and the electrical power grid. Extreme space weather events—those that could significantly degrade critical infrastructure—could disable large portions of the electrical power grid, resulting in cascading failures that would affect key services such as water supply, healthcare, and transportation. Space weather has the potential to simultaneously affect and disrupt health and safety across entire continents. Successfully preparing for space weather events is an all-of-nation endeavor that requires partnerships across governments, emergency managers, academia, the media, the insurance industry, non-profits, and the private sector.

It is the policy of the United States to prepare for space weather events to minimize the extent of economic loss and human hardship. The Federal Government must have (1) the capability to predict and detect a space weather event, (2) the plans and programs necessary to alert the public and private sectors to enable mitigating actions for an impending space weather event, (3) the protection and mitigation plans, protocols, and standards required to reduce risks to critical infrastructure prior to and during a credible threat, and (4) the ability to respond to and recover from the effects of space weather. Executive departments and agencies (agencies) must coordinate their efforts to prepare for the effects of space weather events.

Sec. 2. *Objectives.* This order defines agency roles and responsibilities and directs agencies to take specific actions to prepare the Nation for the hazardous effects of space weather. These activities are to be implemented in conjunction with those identified in the 2015 *National Space Weather Action Plan* (Action Plan) and any subsequent updates. Implementing this order and the Action Plan will require the Federal Government to work across agencies and to develop, as appropriate, enhanced and innovative partnerships with State, tribal, and local governments; academia; non-profits; the private sector; and international partners. These efforts will enhance national preparedness and speed the creation of a space-weather-ready Nation.

Sec. 3. *Coordination.* (a) The Director of the Office of Science and Technology Policy (OSTP), in consultation with the Assistant to the President for Homeland Security and Counterterrorism and the Director of the Office of Management and Budget (OMB), shall coordinate the development and implementation of Federal Government activities to prepare the Nation for space weather events, including the activities established in section 5 of this order and the recommendations of the National Science and Technology Council (NSTC), established by Executive Order 12881 of November 23, 1993 (Establishment of the National Science and Technology Council).

On October 18, 2016, President signed Executive Order 13744.

- Executive Order 13744: Coordinating Efforts To Prepare the Nation for Space Weather Events
- "Extreme space weather events…degrade critical infrastructure--could disable large portions of the electrical power grid, …"

This Executive Order has several directives including:

- **Oversite of DOE** to develop a plan to implement a pilot program to deploy, test, and evaluate technology and/or devices (in the field) to prevent or block geomagnetically-induced currents (GICs) from space weather events from entering transformers.

Evaluate GIC blocking devices

DOE GIC Blocker Pilot Program

EPRI is working with DOE to help develop the pilot program plan to protect transformers in the field as directed in Executive Order 13744.

EPRI is providing the following:

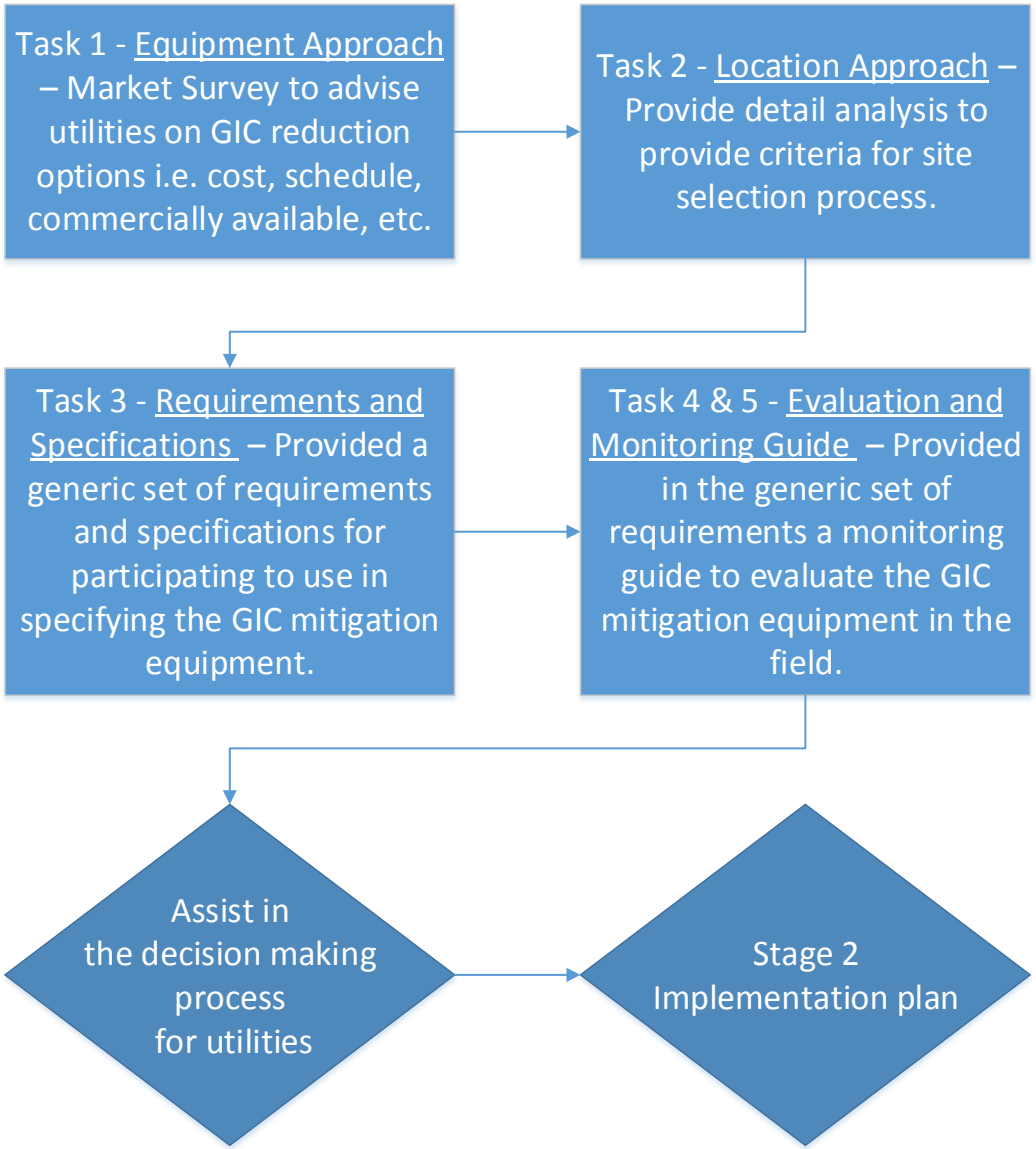
- Market Survey (Completed)
- System approach to selecting sites (Completed)
  - Minimal impact to adjacent substations, positive impact
- Hardware specifications (for monitoring and equipment) (Completed)
- Evaluate GIC blocking devices in the field

Physical representation of a neutral

Phase 1 Project Overview

The information in this report can be used in

- developing an approach/criteria to evaluate viable GIC mitigation equipment and technologies
- determining the number and type of equipment to be purchased and installed to implement the pilot program and
- estimate equipment lead times to be included in a master implementation schedule.



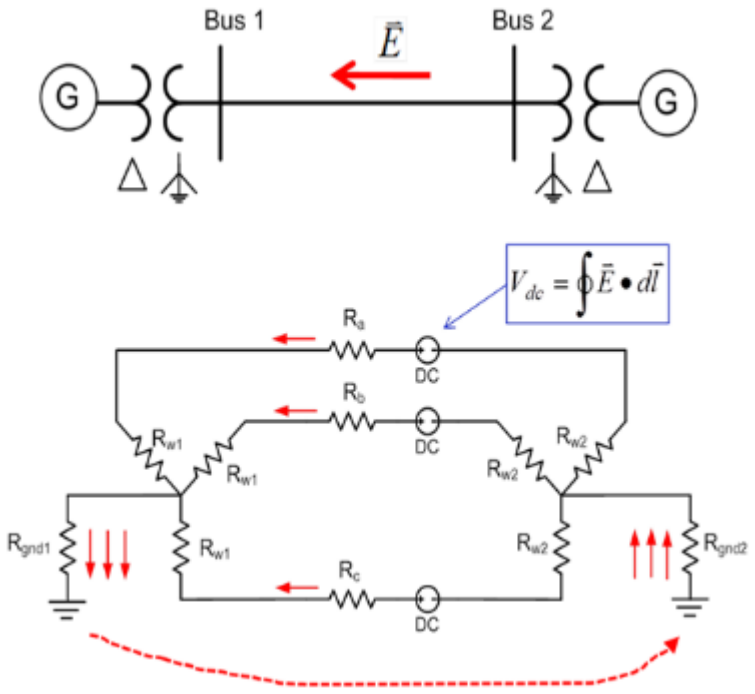
Equipment Approach

	Series compensation Capacitors	Neutral Blocking Devices	Neutral Resistive Devices	Use of a sacrificial MOV (surge arrester) as a GRD	Low capacitance NBD
Commercially Available	✓	✓	✓		✓
Equipment Cost	$12M estimate	$500K	$100k estimate	<$50k estimate	<$10k [estimate]
Installation Costs	$19.5M estimate	$470K	$200k estimate	$100k estimate	$100k estimate
Equipment has been Operational Experience	✓	✓	✓		✓
Lead times	6-8 months	6 months	3 months	minimal	minimal
Additional Considerations	Needs a large amount of space to install.	Greater number of components compared to some GRD methods potentially reducing reliability.	Does not prevent harmonics associated with transformer GIC.	Once the MOV is sacrificed the device no longer blocks GIC.	Transformer will need full insulation level through to neutral.
Relative Study complexity (1-10)	8	10	4	3	2

Location Approach

Developed the recommended approach for determining critical factors, to include appropriate sites for mitigation or protection devices

Provided GIC monitoring recommendations for non-protected transformers in proximity to mitigated or protected transformers.

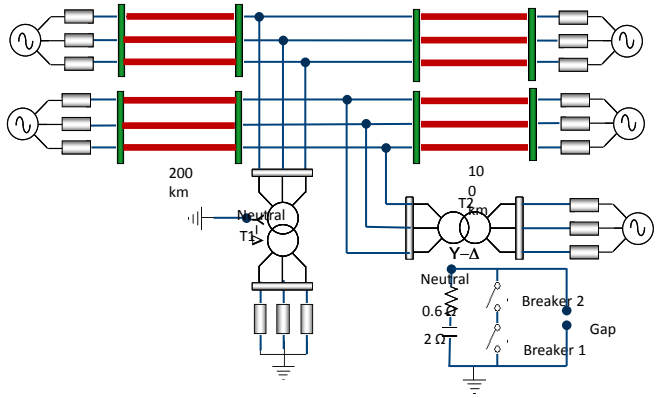


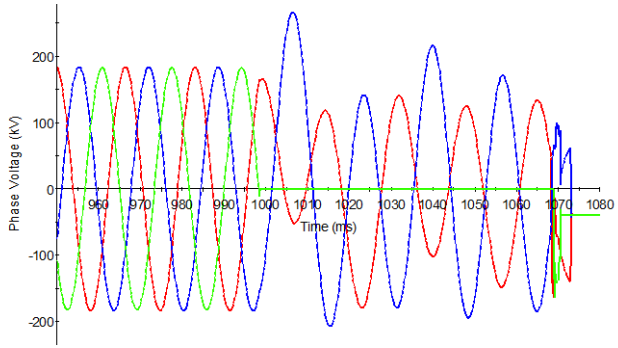
GRD Specifications

Provide an approach to evaluate and specify GIC mitigation equipment and technologies.

Provided generic set of requirements and specifications for GMD mitigation equipment to the utility that will be part of this pilot program.

Those who choose to participate in the pilot program will be able to use this information to develop their own specific specifications.



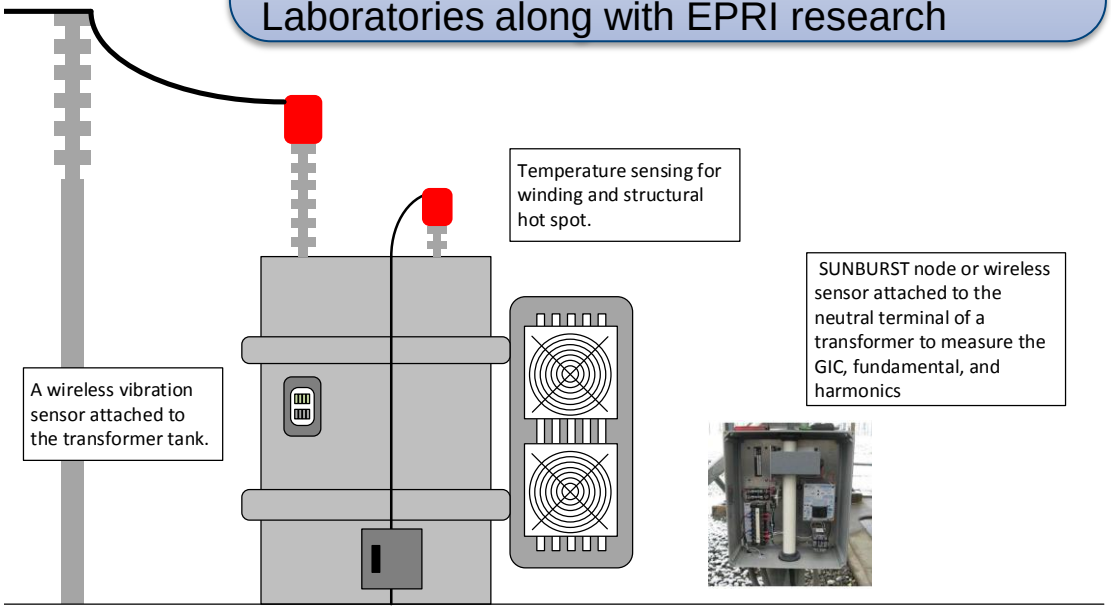


Field Evaluation Monitoring

Evaluating the GRD equipment

Monitor the impact on the protected transformer along with the impact on the non-protected transformers which may see an increase in GIC due to the use of the GRD.

Monitoring recommendations based on the "Geomagnetic Disturbance Monitoring Approaches & Implementation Strategies" report developed by Idaho National Laboratories along with EPRI research



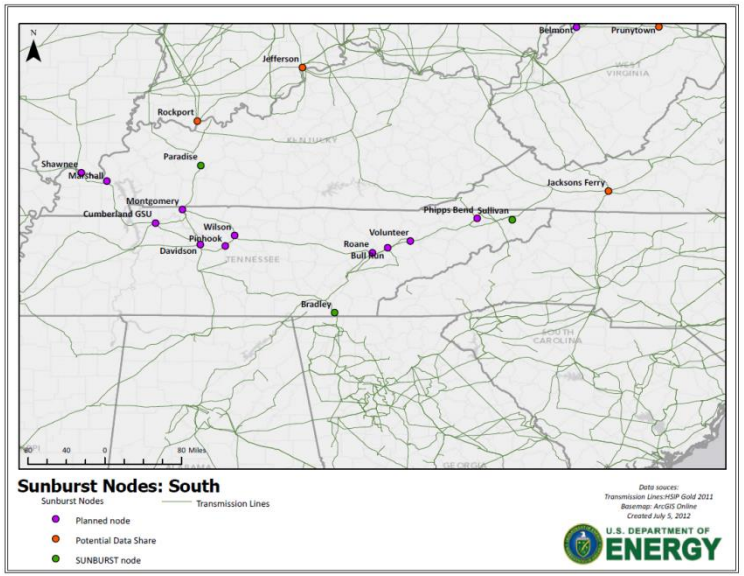
Leverage on SUNBURST Nodes

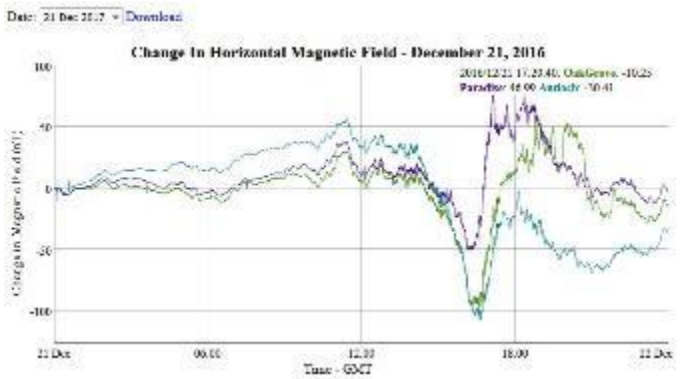
GIC Monitoring: 49 Sites

- Plans for additional sites in 2018

Adding capability to monitor magnetic fields

- Objective: To record B-field variations that drive GICs
- 6 variometers installed and 11 additional sites planned





Participation of Utilities

Stakeholder guidance and utilities' willingness to participate in a pilot program will decide the specific utility and the placement of GRD.

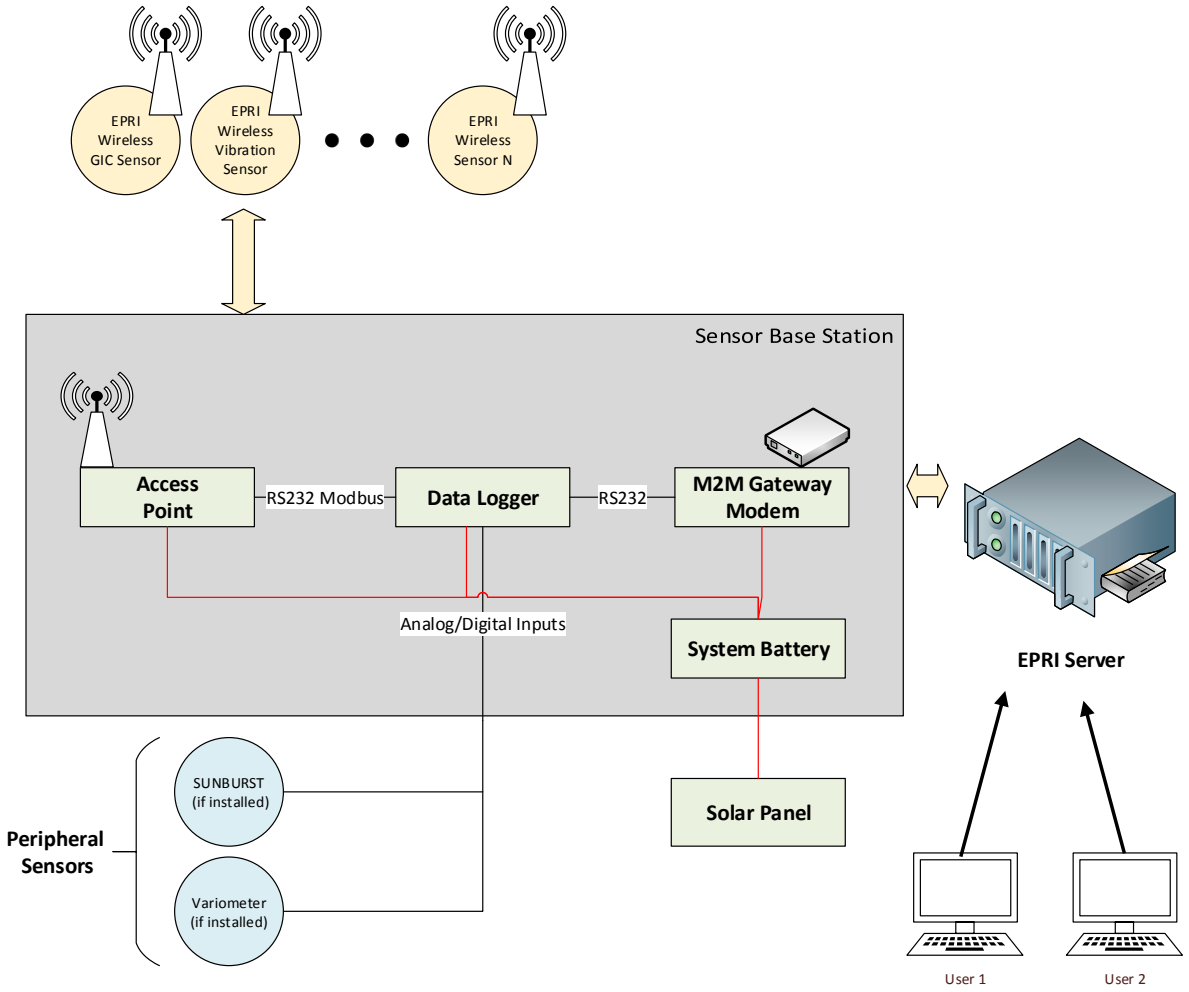
Presently EPRI and the DOE are in communication with three utilities interested in the pilot program.

Ultimately the decision on which GRD to implement on the system is the decision of the participating utility, this information will aid in deciding the number and type of equipment to be purchased and installed.

Next Steps – Proposed Monitoring Architecture

Phase 2 – implementation stage

- Work with utilities participating in pilot program to select site.
  - Criteria and results based on Task 2 of Phase 1 report
- Provide cost estimates and monitoring guidance needed for evaluation.
- Provide data collection and evaluation.



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