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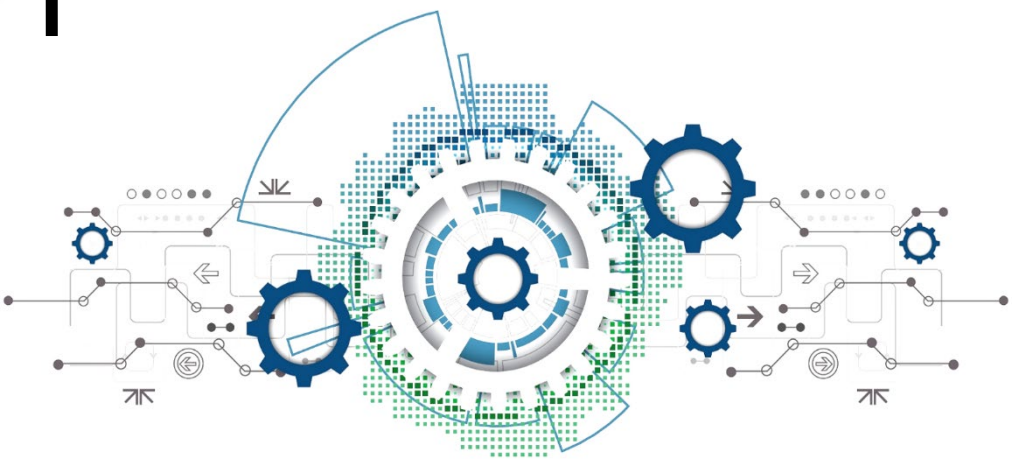
Technology Innovation Projects Closed in Fiscal Year 2023



Technology Innovation Project

Closing Project Brief

TIP 367: EPRI P37: Power Transformer Through-fault Risk Assessment

Context

Transformers are designed to withstand certain levels of stress (number of through faults, fault magnitude and duration) based on their application. Over time as the transformer experiences multiple through-fault events the resulting stress impacts the transformer's survivability. BPA has substation busses with significant fault duty, in excess of 20 times normal rated current during a through-fault event, which can cause over 400 times the normal force on the winding.

In spite of these large forces on the transformer winding, very little research has been performed on quantifying the degradation during through-faults. By contrast, significant research has taken place and continues to take place on evaluating degradation of transformer insulation as the result of heat generated in the transformer during normal and abnormal transformer loading. However, on BPA's Transmission system the mechanical degradation from through-faults is likely as large if not a larger driver of transformer reliability than thermal degradation of paper insulation.

EPRI, with support from member utilities, initiated the development and testing of methodologies that use test, maintenance, nameplate, and historical failure performance to assess transformer condition.

Description

The project approaches the power transformer as a system of major subcomponents, including main body, load tap changer, dielectric fluid, bushings, cooling, and other auxiliaries. Transformers are designed to withstand certain levels of stress such as number of through-faults, fault magnitude, and duration. Over time, as the transformer experiences through-faults, the resulting stress impacts the transformer's future survivability.

The project encompasses the following tasks:

• Catalogue readily available pertinent data

• Develop an assessment methodology

• Develop algorithms

• Investigate transformer application and operational considerations

• Apply algorithms with utility data and review results

• Make appropriate enhancements

• Document methodology approach, results, and findings

The algorithms developed in this project have been added to the Power Transformer Expert System Software.

Benefits

Project results can help utilities reduce capital costs and maintenance through the application of analytics-based approaches for transformer asset management. This project will:

- Improve assessment of transformer susceptibility to through-fault failure.
- Enhance replacement strategies.
- Reduce capital and maintenance costs.

Achievements

This project developed a new methodology to assess the susceptibility of a power transformer to a through-fault failure. The goal was to understand the impact as function of number of through- faults, fault magnitude and duration using readily available data and use results in utility transformer replacement strategy.

Deliverables

A comprehensive final report documenting the underlying methodology, approaches, and results of the above tasks were delivered at the end of the project. Interim status reports and findings for individual tasks were provided periodically.

TIP 367: EPRI P37: Power Transformer Through-fault Risk Assessment

Project Start Date: May 2016

Project End Date: July 2022

For More Information Contact:

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Links

EPRI Program 34: Transmission Asset Management Analytics

Participating Organizations

EPRI

Conclusions

The project evolved over time. The research objective was the development of an algorithm that would calculate through fault risk for a specific transformer using readily available data (design information, PTX normal degradation index, fault history etc.). The model development was completed in the initial phase, 2015-2019. The model is implemented in Power Transformer Expert System Version 7.0 – this version was delivered last year. BPA funded this phase and has access to the latest version of the software.

The latest version includes the ability to calculate a throughfault risk index.

Additional work was identified and needed to inform and validate the analytical model through laboratory testing of reduced scale winding models. Work is currently underway to accomplish this step.

Next Steps: We are doing lab work to validate the assumptions around turn insulation wear. That work involved a shift from the model winding tests mentioned in your last update to a more targeted test set up that allows us to more precisely and repeatably apply mechanical force. We have that test setup complete and are working through a couple of process issues before we ramp up that testing effort.

BPA will continue to monitor this effort.

Technology Innovation Project

Closing Project Brief

TIP 385: Enhancing Hydropower Reliability through Cavitation Monitoring and Noise Condition Assessment

Context

Hydroelectric generation has the flexibility and response characteristics to balance and regulate the grid's intermittent renewable loads. Hydroelectric turbines will therefore be expected to increasingly operate in unexpected hydraulic conditions, including cavitation zones.

Cavitation detection has become increasingly important as erosive cavitation has a direct impact on turbine components integrity and thus on turbine performances and profitability. Many studies were performed focusing on cavitation detection in experimental bench tests with controlled parameters.

A proper monitoring and detection system can provide valuable information regarding operating conditions with high cavitation-erosion potential. Precisely knowing the limits of incipient erosive cavitation can allow adding flexibility to the operating range. Furthermore, avoiding damaging operating conditions can help mitigate cavitation-erosion, which will reduce the number of required cavitation repairs over the years and thus maximize the hydro unit's availability.

Description

This project investigated and developed condition assessment and monitoring methods for hydro turbine-generator units with the aim of minimizing forced outage.

These techniques will be useful tools in the reliability assessment and enhancement toolbox. To achieve this, extensive measurements were carried out in a hydro turbine-generator unit and for a vast range of operating conditions. The dynamic behavior of targeted components were assessed mainly using vibration sensors (accelerometers), acoustic sensors (microphones) and other sensors for secondary measurements (e.g. tachometer, pressure and temperature sensors). The data gathered was used to develop efficient data post-processing components for condition assessment and monitoring purpose. Implementation of these signal processing techniques was then used to develop a monitoring system that will allow data gathering over a long period of time. The resulting data set is then used to validate the cavitation-erosion prediction model and assess the abilities and limits of noise measurements to provide condition and monitoring assessments of various components.

The findings were used to fine tune the monitoring techniques employed and propose definite methods for the tracking and prediction of cavitation-erosion potential, as well as for the condition assessments of several components using mainly noise measurements.

This provides the ability to evaluate in real time the potential cavitation-erosion of a given operating condition and thus help the unit operation decision.

Benefits

The implementation of an operational cavitation monitoring system demonstrator allows the extension of the turbine-generator unit operating range to the limits of incipient erosive cavitation. The system can serve as a guide for the operating team to avoid potential high cavitation-erosion operating conditions.

Ultimately, if applied to several turbine-generator units and integrated in the operation system, this monitoring system can greatly increase the units' flexibility and reduce the number of cavitation repairs needed in the hydro projects that BPA operationally supports and maintains. In addition to significantly reducing the costs for cavitation repair campaigns, the minimization of required cavitation repairs would result in maximum availability of hydropower units for BPA to meet its balancing reserves and customer power demands. Though difficult to quantify, such operating range widening and forced outage reduction will likely result, over the long term, in significant cost reductions for BPA.

Accomplishments

This project succeeded in achieving its goals to:

1) Develop a cavitation-erosion monitoring method that will be implemented in a monitoring system demonstrator, and

2) Determine the feasibility of using noise measurements for condition and monitoring assessments of hydro turbine-generator unit components.

Deliverables

Project deliverables include reporting and presentations for interim tasks.

These include: reporting on test procedures and measurement campaign, analysis of data, programs and routines, as well as recommendations for the monitoring system specifications; results of the monitoring system integration and testing, as well as an overview of the system's installation and commissioning; analyses of data acquired by monitoring system and recommendations of adjustments for subsequent measurements; complete analysis of data acquired by monitoring system and conclusions about the methods investigated.

The final report details the achievements, conclusions and lessons learned of the whole R&D project.

The prototype monitoring system, allowing data acquisition over long time periods will be left at the hydro turbine-generator unit in a fully operational state and will be the propriety of BPA/facility

TIP 385: Enhancing Hydropower Reliability through Cavitation Monitoring and Noise Condition Assessment

Project Start Date: October 2016

Project End Date: June 2022

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Reports,

Final Report: GE/USBR/BPA CRADA (Cooperative Research & Development Agreement)

Participating Organizations

GE Renewable Energy, LLC
Alstom Global Technology Center
United States Bureau of Reclamation

Conclusions:

GE has spent several years studying cavitation in his hydro turbine model test lab. This study further expanded this research on cavitation by applying it to a prototype/field turbine. Through past research performed by GE and the previous CRADA, inspection techniques and algorithms have been developed that determine the severity of cavitation. This additional research verifies that this phenomenon translates well into field performance and it enables further improvements to the previously developed cavitation algorithm through the collection of data from the GE and the USBR installed monitoring systems over the term of this CRADA.

The project was successful in achieving its goals as outlined and detailed in the projects interim and Final report. The information is confidential and distribution authorized only to individuals within the program.

Next Steps

Further collaborative research is proposed with the following objectives:

1- Analyze the Monitoring data: Build specific Cavitation Signature Hill Chart for each cavitation type
2- Cavitation Topology: Determine the cavitation topology over the operating range
3- Cavitation Erosion Model: Determine the erosion rate for each type of cavitation
Calculate the cumulative runner erosion weight
Predictive maintenance
4- Mechanical Solicitation: Monitor the unit stability parameters

Technology Innovation Project

Closing Project Brief

TIP 405: CEATI - Kaplan Turbines Oil Leak Elimination

Context

An oil spill from a hydroelectric facility can cause environmental impacts, and Kaplan turbines in particular present additional challenges because of the volume of oil used for these units and the close proximity of oil to the aquatic environment. The hub of a Kaplan turbine is typically filled with pressurized oil to equalize the pressure compared with the outside water passage pressure, as well as to lubricate the internal mechanisms. The blade servomotor also uses oil as a hydraulic pressure fluid.

For the last 100 years, the overall risk to the natural environment from an oil leak from Kaplan hydro units has been accepted as being low. However, due to greater public awareness and changes to environmental regulations, the hydro industry is more committed to the minimization, if not the elimination, of this risk.

Description

This CEATI International project produced a comprehensive study analysis of high level options outlining the opportunities and alternatives to achieving the goal of minimizing, and where feasible eliminating, the risk of Kaplan turbine oil leakage.

The project methodology included completion of a member survey:

CEATI gathered information from the HPLIG members who have experience with Kaplan turbines and particularly those having experience with oil leakage issues and associated corrective actions. The intent of this **request for information (RFI)** is to better understand the various failure modes and resultant risks that may accompany the operation of some existing Kaplan turbines.

The survey included a cross-sectional drawing of a typical Kaplan turbine hub that illustrates seven different potential oil leakage paths (failure modes resulting in direct oil release to water). Members responded with information specific to their experiences. The results were compiled and shared at a HPLIG workshop.

Further, the program sponsored a 2-day webinar series where members presented on the topic of Kaplan turbine oil leaks and potential strategies for their elimination.

Benefits

This project advances the industry's goal of minimizing or eliminating oil release into the aquatic environment, which directly relates to the primary hydro generation industry goal of meeting corporate, public & regulatory stakeholder expectations.

The findings of this study helps Kaplan turbine owners identify both a near-term and a long-term strategy to address the well-known issue of oil leakage. Although not a current regulatory requirement to convert units, proactive demonstration of positive action to improve environmental performance and corporate responsibility will allow for long term capital programs to be planned and approved.

Because there is an industry imperative to best manage the inherent oil leakage problem by acting proactively, the results from this project may also avoid cost penalties, environmental damage, imposed stricter regulations, generation curtailment, etc.

Accomplishments

As outlined in the following objectives, the focus of this study provided guidance on existing/in-situ oil-filled Kaplan's and "what to do?" alternatives. The longer-term goal of this interest group will be to identify technology changes that can be undertaken to install new oil-less Kaplan technology.

The objectives of this study were to:

- identify ways to detect oil leakage and then reduce or eliminate it
- find the critical components that prevent oil leakage and find ways to improve them
- register available methods and project experiences for reducing oil leakage
- find environmentally friendly hydraulic fluids that could replace oil
- describe most cost effective ways to customize, rebuild or change existing Kaplan units so that oil leakage can be reduced/eliminated.

Deliverables

The project deliverables include information addressing the scope and objectives outlined above. Additionally, a review of best practice fluids and seal materials and seal designs, and case studies of oil leak elimination.

TIP 405: CEATI - Kaplan Turbines Oil Leak Elimination

BPA Start Date: May 2019

BPA End Date: November 2020

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Links

CEATI Kaplan Turbine Oil Leak Elimination

Participating Organizations

Centre for Energy Advancement through Technological Innovation (CEATI International)

Conclusions

The project sponsors identified the most probable failure modes using the Kaplan cross-section diagram and collected requests for information (RFI) data from a number of utilities on perceived risk of these failure modes. A compiled abbreviated failure mode list is included with the RFI results (failure mode catalog).

Participation in this interest group resulted in a series of member-driven webinars providing information on Kaplan Oil Leak subjects including:

- Kaplan Sealing
- Oil Accountability
- Trunnion Seal Replacements
- Oil Leak Elimination

TIP 427: CEATI - Energy and Integration Strategy Interest Group (E&IS) formerly SOIG

Context

The Energy and Integration Strategy Interest Group was previously known as SOIG, the Strategic Options for Integrating Emerging Technologies and Distributed Energy Interest Group. It is an international consortium of electric utilities with a common focus to scout, evaluate, and demonstrate various emerging technologies and grid options that, whether standalone or in concert, will enable a net zero carbon power system, while maintaining resource adequacy, grid reliability, and affordability. E&IS concentrates predominantly on edge-of-grid technologies, and their enablers. These include technologies such as storage devices, micro-interconnects, and system-controlled demand response applications. Consideration is given to the transformation of the energy system including energy carriers (e.g., hydrogen, ammonia, biofuels), and requirements for economy-wide electrification. The question of associated transmission and distribution designs/paradigms to support more renewable integration and supply are also considered. The program has a wide, forward-looking breadth that is relevant to generation, transmission, distribution, and ISOs.

This program is updated annually and contains specific objectives and targets outlined in the yearly Action Plan.

Key Activities

The E&IS program covers primarily resources on the generation side of the interconnect as defined by the interconnection agreements in the jurisdiction. Note that the program scope also includes high-level analysis of the technology and economic changes on the grid-side that will be required to support these grid-edge devices and associated grid transformation paradigm. E&IS participants must consider these aspects as options in the holistic pathway to net zero carbon, while maintaining reliability, resiliency, and affordability.. The ten areas described below reflect the current key interests for the E&IS participants:

1. Energy Storage, scenario planning, and techno-economic trending
2. Utility-scale generation
3. Distributed energy resources
4. Alternative fuels
5. Carbon Capture, Utilization, and Sequestration
6. Integration
7. Remote communities
8. Other innovative solutions (e.g. Demand-side management as a resource, blockchain)
9. High-level grid-side changes required in T&D to support new and high levels of grid-edge technologies.
10. New business models and opportunities

Benefits

The interest group enables its participants to enhance their knowledge via information exchange as well as through project co-funding opportunities that will lead to the development of practical innovations that can be readily applied to today's challenges. It brings together participants involved with sustainable power generation and related industries to identify and assess emerging technologies in renewable energy, distributed energy resources, greenhouse gas emissions, energy storage, and electric transportation.

Accomplishments

The core mission of the Energy and Integration Strategy (E&IS) interest group is to support the strategic planning of participating member utilities by monitoring developments and trends around technology, economics, markets, policy, and regulatory changes that may be transformative – disruptive or beneficial – to the utility business model.

Membership in this program provided BPA a better awareness of industry and government collaborative efforts.

Deliverables

Participation in the interest group provided BPA with access to reports, webinars and presentations. Project reports are available for the tenure of participation in the interest group upon request. See Result section for details.

TIP 427: CEATI - Energy and Integration Strategy Interest Group (E&IS)
formerly SOIG

Participation Start Date: September 2020

Participation End Date: December 2022

For More Information Contact:

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technologyinnovation@bpa.gov

Links

CEATI - Energy and Integration Strategy

Results

The scope for the Energy and Integration Strategy Interest Group is to study, evaluate, and demonstrate sustainable emerging technologies that will result in an increase in clean and renewable power supply capacity and a reduction in greenhouse gas emissions. This includes technologies for the integration of distributed, intermittent, and emerging generation, and the enablers of these new generation technologies - storage, microgrids, and demand response. The interest group also focuses on techno-economic scenario planning and forecasting.

Over the course of participation in this interest group, BPA collected many reports for distribution among interested agency work groups.

Among the project reports this interest group has produced are:

CEATI Report No. T182700-0547: HOW LOW CAN THE COST OF ENERGY STORAGE GO?

CEATI Report No. T202700-0549: METHODOLOGIES TO OPTIMIZED THE VALUE AND AMOUNT OF ENERGY STORAGE:
Economic and Technical Evaluation
Energy Storage System Valuation Tool

CEATI Project No. T1 32700-0550: HYDROGEN PRODUCTION, TRANSPORTATION, STORAGE & MARKET UTILIZATION POTENTIAL
Technical and Economic Review
Hydrogen Financial Tool Guide

CEATI Report No. T0 32700-0551: OPTIMIZING SOLAR PV + DC-COUPLED ENERGY STORAGE SYSTEMS

CEATI Project No. T1 32700-0552: END-OF-LIFE MANAGEMENT FOR WIND, SOLAR PV, AND LITHIUM-ION BATTERY ASSETS: Technical & Economic Review

CEATI Project No. T222700-0553: GRID-INTERCONNECTED POWER CONVERTER PERFORMANCE AND RELIABILITY: Technical Evaluation

CEATI Project No. T1 32700-0540: ENERGY STORAGE SCOPING STUDY:

For these and other reports from this interest group, contact Technology Innovation.

TIP 432: CEATI – Vegetation Management (VM)

Context

The effective management of vegetation on transmission and distribution corridors is essential to the reliable supply of electricity and to ensure public and worker safety. Vegetation programs must also comply with new and emerging regulations, meet public and landowner expectations and consider environmental issues. Managing vegetation can range from pruning or removing individual trees to encouraging the establishment of low growing compatible plant communities on a right-of-way. Furthermore, it involves responding to public, First Nations, Government and landowner requests and concerns, while still achieving control that will comply with NERC and other regulations in a cost effective manner. These are a few of the aspects needed to develop a comprehensive and effective vegetation management program.

Focus Areas

The CEATI Vegetation Management Program focuses on many of the areas noted above with an emphasis on asset management and program planning, as opposed to specific work specifications required for fieldwork.

The following areas have been identified by members as important to VMP's mission. It is anticipated that this list will develop and evolve over time.

- Adapting and Implementing Technology Solutions to Vegetation Programs
- New Materials and Techniques
- Environmental Issues, Requirements, and Compliance
- Vegetation Management Program Optimization
- Responsible Vegetation Management Practices
- Strategies for Public Notification and Consultation

Benefits

The VMP group provides vegetation managers with a cost-effective vehicle for sharing experiences and addressing issues pertinent to their day-to-day operations, maintenance, and planning. The primary benefit of program participation lies in the opportunity to tap into the wealth of experience and knowledge of other transmission & distribution electrical utility participants, allowing members to learn from the mistakes and successes of others.

Accomplishments

CEATI's Vegetation Management Program creates networking opportunities for vegetation managers and connections with subject matter experts. These connections support making improvements in utilities' vegetation management programs.

Deliverables

As a participant in this interest group BPA gained empirical evidence, performance data, recommendations, and best practices to inform the Agency's future measures development and improvement (see Reports).

CEATI VM Collaborative Projects

- Vegetation Management Cost Benefit of Herbicide Use
- Control of Weeds in Electrical Facilities such as Substations, Switchyards, Capacitor Stations, & Cable Termination Sites
- Powerline Vegetation Management Best Management Practices Within Boreal Woodland Caribou
- Improving Vegetation Management via Wearable Technology and Augmented Reality
- An Analysis of PhoDAR vs LiDAR For Collecting Spatial Data by Electrical Utilities and Operational Recommendations for Use

2023 Program Activities

The Vegetation Management Action Plan for 2023 takes its lead from the Vegetation Management Strategic Plan. All the activities in the Action Plan aim to deliver value to Vegetation Management members. Vegetation Management program covers topics from the following Focus Areas:

- Focus Area 1 – Strategic Planning and Program Management
- Focus Area 2 – Technology, Equipment and Products
- Focus Area 3 – Public and Social Opportunities
- Focus Area 4 – Environmental Contributions

Each of the activities in the Action Plan has been identified by Vegetation Management members. All activities in Vegetation Management are driven by its members.

TIP 432: CEATI – Vegetation Management (VM)

Project Start Date: January 2020

Project End Date: Membership

Links

CEATI - Vegetation Management

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2023 Program Activities (cont)

Information and materials from these events can be found on the Vegetation Management Program Page at www.ceati.com.

MEETINGS

- Vegetation Management Benchmarking Session - American Electric Power Oct 19, 2023
- VM RFP 23.01 Proposal Review & Discussion with Grow with Trees Oct 18, 2023
- Vegetation Management 2023 Spring General Meeting May 9, 2023
- Q1 Winter Conference Call Jan 19, 2023

WEBINARS

- Vegetation Management Fall 2023 General Meeting
- Nov 13, 2023 Fort Worth, TX
- Climate Ready Vegetation Management Programs in Transmission Rights of Way (ROW): Habitat value and ecological return on investment (EROI) Sep 19, 2023
- VM End-of-Project Webinar: Best Management Practices for the Effective Customer Communication of Vegetation Management Mar 28, 2023
- VM End-of-Project Webinar: An Analysis of PhoDAR vs. LiDAR for Collecting Spatial Data by Electrical Utilities and Operational Recommendations for Use Mar 7, 2023

Reports

An Analysis of PHODAR vs. LIDAR for Collecting Spatial Data by Electrical Utilities and Operational Recommendations for use; S. McArdle, et al; CEATI REPORT No. T203700-4105

Best Management Practices for the Effective Customer Communication of Vegetation Management; LiveEO GmbH, Berlin, Germany; CEATI REPORT No. T213700-4107

Conclusions

BPA had limited interest in these areas and chose to discontinue membership in this interest group. In general, the subjects are covered with BPA Vegetative Management's relations with other similar industry groups including: The North American Transmission Forum (NATF) Vegetation Practices team; International Wildfire Risk Management Consortium (IWRMC); International Society of Arboriculture (ISA); and the Utility Arborist Association.

BPA Vegetative Management will consider collaboration on a limited basis in the future if something new is added to the list of projects CEATI is working on with respect to vegetation management.

Technology Innovation Project

Closing Project Brief

TIP 436: EPRI - Sustainability Benchmarking for Utilities

Context

Companies across many industries are increasingly working to understand how to meaningfully track sustainability performance over time and relative to peers. There are a growing number of third-party reporting "standards" companies can follow and an equal number of private consultants offering benchmarking services. Under all of these approaches, specific metrics are used to identify priorities and trends, communicate with stakeholders, track performance against company goals, and compare to peers. It is important under any benchmarking effort to use metrics that properly compare information that was collected using similar methods.

Project Description

The Benchmarking Project builds off the metrics research undertaken through Energy Sustainability Interest Group (ESIG), providing an opportunity to test their applicability, technical validity, and significance. Each year project participants submit their performance data to EPRI's online platform to benchmark with industry peers.

The online benchmarking platform contains a set of sustainability metrics identified as most relevant to the industry by EPRI and ESIG. The database allows users to benchmark their sustainability performance data against other companies who participate in this project and with themselves from year to year.

The project has four main tasks:

1. **Enhance Online Benchmarking Platform Capabilities**

Project participants identify and recommend new or evolved capabilities for version 6.0 of the benchmarking platform. It is possible that a new software platform will be considered.

2. **Update Online Benchmarking Platform**

This task focuses on the engineering, coding, and technical build of the online platform.

3. **Submit Data and Perform Benchmarking**

Project participants have the option to submit data via the online platform and run reports to compare to other companies who also submit data. A formalized EPRI confirmation and data correction process will be undertaken prior to opening the database to participants for graphing and reporting.

4. **Benchmarking Forum Conference**

Project participants may attend a Benchmarking Forum, where funders can review and discuss the benchmarking results and learn from companies that excel in different performance areas.

Benefits

The many metrics in use in the electric power industry have created a heavy burden of reporting. This burden translates into business and customer cost, and may make it difficult to understand and prioritize sustainability performance issues.

This Benchmarking project uses a common set of metrics to collect data and provide the opportunity to benchmark sustainability performance against peer utilities. The project aims to avoid the costly effort of assembling peer data from other sources, as well as facilitate direct engagement and collaboration among participants.

Accomplishments

This update of the benchmarking platform provides a foundation for understanding how companies compare to peers and managing overall performance. This understanding can assist companies in being more sustainable, providing major benefits to efficient operations, community engagement, and employee recruitment and retention.

Deliverables

The non-proprietary results of this work is incorporated into EPRI R&D Program 198, and made available to the public, for purchase or otherwise.

- Access to Online Benchmarking Platform and database
- Benchmarking results compared to other participating companies
- Bimonthly webcasts.
- Benchmarking Forum conference
- Version 6.0 of the online database release

TIP 436: EPRI - Sustainability Benchmarking for Utilities

BPA membership: 2019 to 2023

Links

www.epri.com/sustainability

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Conclusion

Sustainability Benchmarking for Utilities and its products have been incorporated into EPRI's Energy Sustainability Interest Group (ESIG). BPA continues its membership in the interest group under TIP 437. During the separate membership period the following documents were obtained.

- Energy Sustainability Interest Group 2020 (Report No.3002017130)
- Sustainability Benchmarking for Utilities2020 Background (Report No. 3002019642)
- Sustainability Benchmarking for Utilities 2020 Infographic (Report No. 3002020198)
- 2021 Metrics to Benchmark Electric Power Company Sustainability Performance (Report No. 3002021713)
- Sustainability Benchmarking for Utilities-2021 Infographic (Report No. 3002021719)
- Sustainability Benchmarking for Utilities-2021 Public Report (Report No. 3002021720)
- Enhancing Stakeholder Engagement-2021Sustainability Governance Survey Results (Report No. 3002022319)
- Sustainability Reporting Trends-EPRI 2021 Benchmarking Survey Results (Report No. 3002024782)
- 2022 Metrics to Benchmark Electric Power Company Sustainability Performance (Report No. 3002024786)
- 2022 Sustainability Benchmarking for Utilities-2022 Infographic (Report No. 3002025645)
- 2023 Sustainability Benchmarking for Utilities Infographic (Report No. 3002026754)
- 2023 Metrics to Benchmark Energy Utility Sustainability Performance (Report No. 3002026906)

These reports are available upon request to the Technology Innovation EPRI Program Manager.

Technology Innovation Project

Closing Project Brief

TIP 438: EPRI Supplemental – Forest Grove-Tillamook 115kV Outage Monitoring

Context

EPRI has developed a suite for radio frequency (RF) monitors for both substations and overhead line applications. There are multiple types of RF monitors that can be selected in any combination to monitor a line or substation depending on the use case.

Project Description

This project supports BPA's Forest Grove–Tillamook No. 1 (115 kV) Outage Investigation, where a number of unknown outages have occurred.

By deploying two types of the EPRI RF monitors, Leakage Current and Conductor RF Monitors, the root cause could be identified, and certain root causes eliminated, thereby allowing the identification and selection of mitigation approaches. If adopted, the results of this research may also support the future design of transmission lines in the area.

RF Monitors were installed to identify any impacts to the phase conductors from trees and limbs; measure any excessive conductor motion; and measure leakage currents on insulators due to contamination.

In addition, local weather parameters were measured to determine the conditions under which the outages occurred. Analyzing and correlating this data with outage occurrences may offer insights into the root causes.

Two monitoring locations were installed based on a review of the outage report. The RF monitors and base stations were installed, and the data monitored on EPRI IT and data visualization systems for an extended period. This allowed sufficient time to acquire information that would support decision making on whether to engage in more widespread deployment.

Benefits

Understanding of the root causes of outages promotes the reliability of the electric transmission and distribution system to supply energy in the region. Adoption of the research results from this study may also aid in the future of transmission line design, and thereby improve performance and safety in bringing electric power to the public.

Accomplishments

This project successfully accomplished its two main goals:

1. Increase understanding of the unknown outages on transmission lines under study and the potential mitigation approaches.
2. Provide insight into the RF monitor measurements and their impact on informed decision making.

Deliverables

The project provided sensor equipment as well as visualization and analytical tools to support the work.

1. Twelve Leakage Current RF Monitors, Twelve Conductor RF Monitors, Four Cameras and Two Base Stations (Physical Deliverables)
2. Data Hosting and Visualization: Visualized data on EPRI's Data Visualization website for twelve months with alarms.
3. Brief Summary Report of Conclusions and Recommendations

The non-proprietary results of this work were incorporated into EPRI R&D Program 35, and made available to the public, for purchase.

TIP 438: EPRI Supplemental – Forest Grove-Tillamook 115kV Outage Monitoring

Project Start Date: January 2020

Project End Date: December 2022

Links

Electric Power Research Institute

www.epri.com

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Conclusion:

After some delay due to personnel changes, EPRI produced two reports:

Monitor the Issue, Solve the Issue (Report No. 30020172) describing the EPRI Radio Frequency (RF) Monitor Suite, a collection of monitors that provide information on the health of a range of transmission line and substation assets.
Leakage Current RF Monitors (Report No. 3002020173) describing two types of leakage current monitor; one for long rod, composite and substation post insulators, and another for glass or porcelain disc insulators.

These reports are available to the public on the EPRI website or contact BPA's EPRI Program Manager.

Technology Innovation Project

Closing Project Brief

TIP 443: XFACTS-Cyber Resilient Flexible AC Transmission Systems

Context

Transmission organizations today face vulnerabilities associated with insider attacks on operation and control systems, including **Flexible Alternating Current Transmission Systems (FACTS)** with syntactically correct malicious commands and measurements. Opportunities exist to extend FACTS controls into cybersecurity.

Description

A FACTS substation enhanced with XFACTS defense mechanisms is capable of mitigating cyberattacks especially those that seek to control electrical parameters like voltage or current and interrupt the power flow in AC lines. It empowers existing FACTS controllers and associated intelligent electronic devices to detect and mitigate malicious intents to depress system voltages, destabilize power flows, trip AC circuit breakers, corrupt currents, and voltages, even if the malicious commands and the measurements have correct syntax. The XFACTS functions uses the physics of the active power electronic systems, control and protection, electric power engineering principles, and state estimation to bring more in-depth cyber defense closer to the protected FACTS substation devices.

BPA's In-Kind Contributions

XFACTS final test for deployment readiness was staged at a 230 kV AC substation within the Bonneville Power Authority service area. BPA and HE demonstrated the field performance of XFACTS in a substation environment, with staged cyberattacks on the control system and successful defense from the security functions. BPA also provided modeling and technical support in the following areas:

- Allocation of personnel to complete the tasks.
- Lead and supervise the final demonstration of the project in a BPA lab
- Build a high-fidelity real time digital simulator (RTDS) model of a Static Var Compensator (SVC) station and surrounding power system used for the demonstration
- Provided input to the requirements specification of the XFACTS functions

Benefits

The cybersecurity enhancements developed in this project improves FACTS controllers, SCADA/ EMS servers, and other devices with new firmware to support defense mechanisms against cyber vulnerabilities and insider attacks. The system will alert operators with the identity of any malicious cyber commands and measurements acting on FACTS devices.

Accomplishments

The accomplishments of the FACTS project have advanced the state of the art in cyber security of FACTS substations by adding intelligence to existing devices that is based on the underlying physics of the protected electrical system.

The project is a successful example of a government-sponsored, industry/academic partnership. BPA, University of Idaho, Iowa State University, the University of Illinois, and Hitachi Energy established a collaboration that enhanced each organization's strengths.

Achievement of BPA Goals

- The project developed a threat model report to provide guidance for BPA cyber risk mitigation plans.
- The project developed a RSCAD model for BPA system studies related to FACTS protection and control.
- Finally, the cyber-physical security test bed can be used for future simulation of ongoing cyberattacks, their detection and mitigation.

Deliverables

The project deliverables include a final report describing:

- Technology pilot for evaluation and testing
- Demonstration of technology on Static Var Compensators and Series Capacitors
- Threat model document detailing threat scenarios, relevant vulnerabilities, and impact
- RSCAD model of a BPA substation configuration with built-in controller.

Hitachi Energy also provided a project presentation to BPA.

TIP 443: XFACTS-Cyber Resilient Flexible AC Transmission Systems

Project Start Date: January 2019

Project End Date: April 2022

Reports

Final Report: Cyber Resilient Flexible Alternating Current Transmission Systems (XFACTS): FINAL SCIENTIFIC/TECHNICAL REPORT – Hitachi Energy (DE-OE0000897)

Hitachi Energy-Project Presentation to BPA

Related Projects

TIP 335: ABB Collaborative Defense of Transmission and Distribution Protection and Control Devices against Cyber Attacks

TIP 397: Cyber Attack Resilient HVDC System – DOE CEDS Initiative

Participating Organizations

US Department of Energy: Office of Cybersecurity, Energy Security and Emergency Response (CESER) (project sponsor)

ABB Enterprise Software Inc., a subsidiary of Hitachi Entergy Ltd. (project lead)

Bonneville Power Administration (BPA) (testing lead and project support)

University of Illinois at Urbana Champaign (UIUC)

Iowa State University (ISU),

University of Idaho (UI)

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Results

The tasks developed during the project followed the project plan and consisted of: threat model specification for FACTS stations, wide area measurement systems controlling FACTS and SCADA systems controlling FACTS; development of control logic extensions that detect intrusion on normal and emergency FACTS control commands; design of a streaming state estimator that detects false measurement injection attacks on the FACTS communication system; FACTS control devices; validation of the FACTS security algorithms in a hardware-in-a-loop laboratory setup at Hitachi Energy; and field demonstration of the developed system of FACTS cyber security functions and devices at Bonneville Power Administration (BPA) within their Ross AC substation.

The Hitachi Energy Research team transferred the developed technology to HE FACTS product groups for inclusion into their product roadmap.

Conclusions

The defense mechanism against the cyber-attack on the primary controller of the STATCOM was designed and performance evaluated by measuring dependability (ability to detect cyberattack) under different kinds of sensor attacks, including scaling attack, bias attack, and delay attack. These attack scenarios on the DC voltage, AC current, and AC voltage sensors were simulated, measured and dependability detected by the defense mechanism. The performance in case of the external disturbance was also evaluated by applying voltage dip at the PCC. The ability to differentiate disturbance from the cyber-attack was measured and demonstrated in terms of security.

TIP 444: Accelerated Data Analytics for Power-system Time-series (ADAPT)

Context

In recent years, utilities have made great strides in installing phasor measurement units (PMUs) and utilizing the data they provide. Synchrophasor measurements can be used to monitor and control power systems, but they are also valuable for offline analysis. Recognizing this, utilities often make large investments to store collected measurements in archives that can span years. Due to the sheer volume of the data, it can be challenging for utilities to extract value from their archives.

Project Description

This project addresses one of the Artificial Intelligence research priorities within the High Impact Events topic. Synchrophasor and waveform measurements are valuable for performing the required training of artificial intelligence applications, but to use them effectively many examples of high-interest events are required. The ADAPT tool will allow BPA to identify training events in large measurement archives.

The ADAPT software developed in the project will enable BPA to rapidly read, process, analyze, and review synchrophasor and waveform data.

The analytics to be included in the ADAPT software were developed in an earlier project by Pacific Northwest National Laboratory (PNNL) with funding from the Bonneville Power Administration (BPA) and DOE. They were deployed in the open-source Archive Walker tool, which was designed to read and examine archived PMU data for events and system conditions warranting further analysis. The Archive Walker has proved to be a valuable research tool, but transferring the technology to open-source industry-grade software is necessary to make its capabilities readily available for practical use by BPA and other power system operators.

Benefits

With the greater capabilities developed in Archive Walker with BPA's support, the application is available in a much more user-friendly package. Additionally, the open-source ADAPT software can be used by BPA as-is or integrated into custom applications.

Accomplishments

The ADAPT project increases the value of synchronized measurement archives by enabling utilities to rapidly read, process, analyze, and review data. This was accomplished by integrating advanced signal processing and event detection methods into the open-source suite of tools offered by Grid Protection Alliance (GPA)

Goals for BPA included:

- Repackage the capabilities developed in Archive Walker with BPA's guidance into a much more user-friendly package.
- The open-source ADAPT software can be used by BPA as-is or integrated into custom applications

Deliverables

- Requirements and Design document
- Alpha version of the ADAPT software
- Documented marketing strategy
- Beta version of the ADAPT software delivered to at least one utility partner
- Final version of the ADAPT software posted online

Note: These deliverables are based on agreements between DOE, PNNL, and GPA. Project deliverables were not due to or from BPA.

TIP 444: Accelerated Data Analytics for Power-system Time-series (ADAPT)

Project Start Date: February 2021

Project End Date: January 2023

Related Projects

TIP 350: Power Plant Dynamic Performance Monitoring Center

Reports

Accelerated Data Analytics for Power-System Time-Series (ADAPT) Final Project Report; J. Follum, et.al. *PNNL-3387*

Scientific tools for advanced synchrophasor data analytics with the PI System; J. Follum, C. Lackner; AVEVA PI World presentation

Detecting and Analyzing Power System Disturbances in PMU Data with the Open-Source Archive Walker Tool; *2020 IEEE/PES Transmission and Distribution Conference and Exposition (T&D):* INSPEC Accession Number: 20339780

Project members include:

Pacific Northwest National Laboratory (PNNL)

Grid Protection Alliance (GPA)

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Conclusions

With this project, the GPA and PNNL successfully led the technology transfer and the development of SciSync-Scientific Tools for Advanced Synchrophasor Data Analytics under DOE's Technology Commercialization Fund. Its been called the Archive Walker 2.0 due to its improvements and enhancements made to the core functionality available in the Archive Walker software.

The Archive Walker Software and associated functionality were primarily funded by the Bonneville Power Administration through its Technology Innovations Program, with funding associated with projects TIP-348, TIP-349, and TIP-350. Further improvements were funded by the U.S. Department of Energy's Grid Modernization Laboratory Consortium under project GM0072.

Bonneville Power Administration contributed to the project by providing access to the field-measured data used in testing. According to SciSync, the project would not have been a success without these contributions.

Further information on this tool and its applications are available in the project's final report noted above.

Technology Innovation Project

Closing Project Brief

TIP 446: CEATI – SEL: Protection System Maintenance Guide

Context

CEATI member utilities maintain their protection relays on different time intervals. Electromechanical relays are typically maintained once every 3 years. However, microprocessor-based relays vary from 3, 6, or 12 years. Moreover, what types of tests are required to verify relay functionality also vary amongst members. **North American Electric Reliability Corporation (NERC)** (for utilities that own NERC applicable protection systems) has defined a minimum level of testing and frequency with which utilities must comply to avoid receiving penalties. NERC standards also dictate varying maintenance intervals for electromechanical versus microprocessor-based protection systems.

Project Description

This project intended to develop guidance for the CEATI members tasked with developing protection maintenance plans or asset management programs that will comply with NERC standard PRC-005-6. The guide addresses what type of testing is required, how often, as well as how protection system designs and monitoring contribute to decreased testing frequencies while complying with NERC standards. Another consideration is when to use time versus conditioned based testing, and what that means.

SEL defined how to use a **substation data acquisition gateway (RTAC)** to use standardized protocols to perform "dynamic and automatic protection asset supervision, health and behavior auditing, and condition based maintenance recommendations"

The guide supports predictive alarming and the production of the necessary data to keep power system components online and avoid expensive downtime.

In addition, the data may be used to:

- Track changes in device settings,
- Compare power system measurements,
- Monitor communication channels, and self-diagnostics, Generate automated reports and log maintenance alerts

This guide can also support protection relays and scheme testing plans, provide protection design attributes that need be incorporated, as well as testing methodologies and other general recommendations.

Benefits

The use of SEL protection, monitoring, and communications equipment, coupled with equipment diagnostics information, improves system reliability, and enables health-based control of substation equipment. The practice of periodic maintenance in hopes of avoiding problems is replaced with real-time monitoring and management of apparatus.

The wealth of information available from the SEL solution enables utilities to perform appropriate maintenance by knowing precisely when to perform tasks based on equipment health and performance. Knowing what needs to be done allows field crews to arrive prepared to perform all necessary maintenance at a particular location during their visit

The RTAC can be used to turn asset management data into information to help maintenance personnel make timely and informed decisions.

Accomplishments

The project developed standardized protection system maintenance best practices and guidance for electromechanical and microprocessor-based protection control systems. This guide provides aid in complying with regulations and monitoring critical assets.

Deliverables

Schweitzer Engineering Laboratories, Inc. (SEL, Inc.) provided a guidance document, 3909 Protection Relay Firmware CIP Compliance Guide – CIP-007 that will address what type of testing is required, how often, as well as how protection system designs and monitoring contribute to decreased testing frequencies while complying with NERC standards. This guide will also address protection relay and scheme testing plans, protection design attributes that need be incorporated to allow testing, testing methodologies, and general recommendations.

TIP 446: CEATI – SEL: Protection System Maintenance Guide

Project Start: January 2021

Project End: December 2022

Links

CEATI Protection and Control Collaborative Program

Project Partners:

SEL Schweitzer Laboratories, Inc. (SEL)

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Conclusion:

TIP 446 is complete, CEATI: Published the following guide:
3909 Protection Relay Firmware CIP Compliance Guide – CIP-007

Additional reports:

CEATI Report No. T213700-3910 Protection Routine Maintenance Guide and Testing per Standard PRC-005

CEATI Report No. T163700-30/112 NERC PRC-005 Best Practices for Compliance

Technical Brief: NERC PRC-005 Best Practices for Compliance

Presentation: NERC PRC-005 Best Practices for Compliance

TIP 447: CEATI – Best Practices for Incorporating Probabilistic Planning into Transmission Planning

Context

The utility industry is experiencing unprecedented changes including integration of renewable generation (primarily solar and wind) driven by public policy requirements to combat climate change. As a result, use of the transmission systems are beginning to change requiring more flexibility than it was designed for. North American utilities follow the criteria contained in the **North American Electricity Reliability Corporation (NERC)** Standard "Transmission System Planning Performance Requirements" when planning their transmission systems. The current version of this standard is TPL-001-4, and it contains deterministic criteria. That is, it does not explicitly consider the probability of a particular contingency occurring. More cost effective planning could be achieved if the probability of a particular event were to be considered when planning new facilities, alongside applying the criteria contained within TPL-001-4.

Project Description

The CEATI project focuses on many of the areas noted above with an emphasis on asset management and program planning. Tasks include:

1. ***Review the literature***: Review and assess the state of industry practice in probabilistic assessment of transmission systems.

2. Review Institute of Electrical and Electronics Engineers (IEEE) Composite System Reliability Task Force: Share knowledge between transmission planners about the effective use of probabilistic planning within the overall transmission planning process.

a. To summarize findings from IEEE probabilistic practice and **S**urvey on **Cyber Security & Resilience (CSR)**

b. Survey conducted with member utilities of CEATI

3. Survey mailed to utilities by CEATI and analyze responses. Recent survey of industry practices in probabilistic assessment and composite system reliability analysis conducted by IEEE Composite System Reliability Task Force

4. Summarize findings: Identify impediments that may be constraining the widespread implementation of transmission probabilistic assessment

5. Identify suitable tools: Identify commercially available tools that facilitate elements of probabilistic planning and list the purpose and data requirements of these tools.

Benefits

The fundamental objective of power system planning is to develop the system as economically as possible and maintain a high level of reliability. Utilities across globe primarily use deterministic criteria that show some weaknesses in the planning practice. By taking into account probabilistic elements, the results of this project can be used to identify more effective (and therefore, more cost efficient) transmission options to incorporate into their system.

Accomplishments

This project achieved its goals to share knowledge between member transmission planners about the effective use of probabilistic planning within the overall transmission planning process and identifying suitable tools for carrying out probabilistic planning. These accomplishments are described in the project final report.

Deliverables

Participation in this project provided BPA with access to the following reports:

1. **CEATI Report No. T213700-3143:** Best Practices for Incorporating Probabilistic Planning into Transmission Planning
2. **Presentation:** End of Project Webinar - Best Practices for Incorporating Probabilistic Planning into Transmission Planning

TIP 447: CEATI – Best Practices for Incorporating Probabilistic Planning into Transmission Planning

Project Start Date: July 2021

Project End Date: June 2022

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Links

Transmission Planning & Operations (TPO)

Formerly Power System Planning and Operations

Results

Considerable work published over the last several decades show that probabilistic risk-based reliability approaches have been widely applied to the planning of generating systems, and a set of probabilistic criteria have been accepted by electric utilities. On the other hand, probabilistic-based approaches for evaluating transmission planning projects have not been widely adopted or applied by utilities.

Maintaining an adequate level of power grid reliability is a challenging problem that utilities today face due to frequent extreme events (e.g., failure of multiple physical components, natural disasters, cyberattacks) and the increasing complexity of energy system infrastructure.

The survey “Best practices for incorporating probabilistic planning into transmission planning” was conducted with CEATI member utilities, and the findings are presented in the final report. This report also presents important issues related to system planning: challenges, current progress, gaps, and future work.

BONNEVILLE POWER ADMINISTRATION

Technology Innovation Project

Closing Project Brief

TIP 454: EPRI PS173D – Bulk System Integration of Renewables and Distributed Energy Resources – Technology Transfer

Context

Installed capacity of renewable energy has increased significantly in the past fifteen years due to policy decisions such as state-mandated renewable energy standards and federal air and water standards, along with cost reductions, and customer preferences. Recent announcements at federal, state and utility level demonstrate significant ambitions to increase clean energy, including renewables and battery storage, to meet decarbonization goals.

Much of the existing and expected development of renewables comprises ***variable and/or distributed energy resources (VER/DER)*** such as onshore and offshore wind generation and solar photovoltaics (PV), which when integrated with the grid, create new challenges for maintaining reliable system operation. Emerging technologies such as battery energy storage, demand response and increased energy system integration are also expected to support these new resources.

Project description – 2022 Key Activities

In 2022, EPRI's Bulk System Renewables and Distributed Energy Resources Integration research program provided its members a focused research portfolio with the following objectives:

- Continue to: a) develop and validate wind, solar and hybrid plant generic models for system planning and protection studies, b) develop and validate models and tools for studying grid weaknesses, and c) investigate grid-forming inverter controls.
- Continue to: a) improve positive-sequence DER models, b) provide default model parameters and associated software, and c) provide co-simulation of transmission and distribution.
- Develop, validate and transfer to vendors: a) models that adequately represent the short-circuit response of wind and solar PV generators, b) guidelines for protection studies and tools for parameterization.
- Develop and demonstrate methods and tools to determine operating reserve requirements, including consideration of risk with contingency events, and the use of probabilistic forecasting.
- Develop methods, models, and tools that can adequately assess the inertia and primary frequency response of a system, including the contribution of VER and other resources.
- Develop methods and tools to assess resource adequacy with a changing generation mix, including the capacity contributions of wind, PV, battery energy storage and demand response.
- Provide guidance on scenario development practices for planning studies.
- Facilitate and inform members of developments of industry standards related to VER/DER, such as the IEEE 1547 and IEEE P2800.
- Increased consideration of the planning and operational implications specific to offshore wind energy.
- Understand planning and operational impacts of energy systems integration, including gas-electric coordination and interaction, and increased electrification of transport and heating sectors.
- Examine issues related to operating and planning power systems when renewables make up a very high portion of instantaneous or average load, up to 100%.

Benefits

With the rapidly changing landscape for renewable and DER integration into the bulk system, deliverables that have broad application are needed to support industry practitioners. Webcasts, short summary reports and videos can enable project set members to share and learn from other's experiences, issues, and solutions. Utility and ISO transmission and resource planners, protection engineers, and operators can use the knowledge provided to assess present industry status of renewable integration and understand their own context compared to other regions. These activities also help identify research and collaboration opportunities.

Accomplishments

The program conducts research projects that lead to methods and tools used by system planners and operators responding to the challenges of high penetrations of VER/DER. These prototype methods and tools are applied and validated by members before being transferred and made available to all relevant commercial vendors that could supply and support member applications.

BPA has received the products applicable to the Transmission Planning group and withdrew further participation in the program.

Application

Primary application is to enhance long-term development and growth of the BPA Transmission program and inform the Energy Efficiency office. The products BPA received during its participation will be used to update and validate current transmission models. New models may be incorporated.

Deliverables

The program produces guidelines and studies to outline how resource adequacy methods may be adapted to the changing resource mix, and how different resources contribute to adequacy. BPA received several products important to updating models used in Transmission Planning.

TIP 454: EPRI PS173D – Bulk System Integration of Renewables and Distributed Energy Resources – Technology Transfer

Project start date: January 2022

Project end date: December 2022

For more information contact:

Technology Innovation:
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Links

Bulk System Integration of Renewables and Distributed Energy Resources (epri.com)

Results and Conclusion

Participation in this project provided important data sets for use in Transmission Planning models:

Reports completed for this project include:

- Advanced Solar and Load Forecasting Operations, incorporating HD Sky Imaging: Phase III Project Report (3002026232)
- Program on Technology Innovation: Multi-terminal VSC-HVDC Systems (MTDC) for Meshed Onshore and Offshore Applications-Development of a Generic Model for Integration Studies (3002024854)
- Natural Gas Networks and Hydraulic Modeling: Basic Needs for Gas Data Sets (3002024649)
- Guidance on Weather Datasets for Studies: Data Sources and Use Cases for Historical Datasets (3002024375)

BPA received the products from this program that are applicable to the Transmission Planning group and of interest to the Energy Efficiency office. We then withdrew from further participation.