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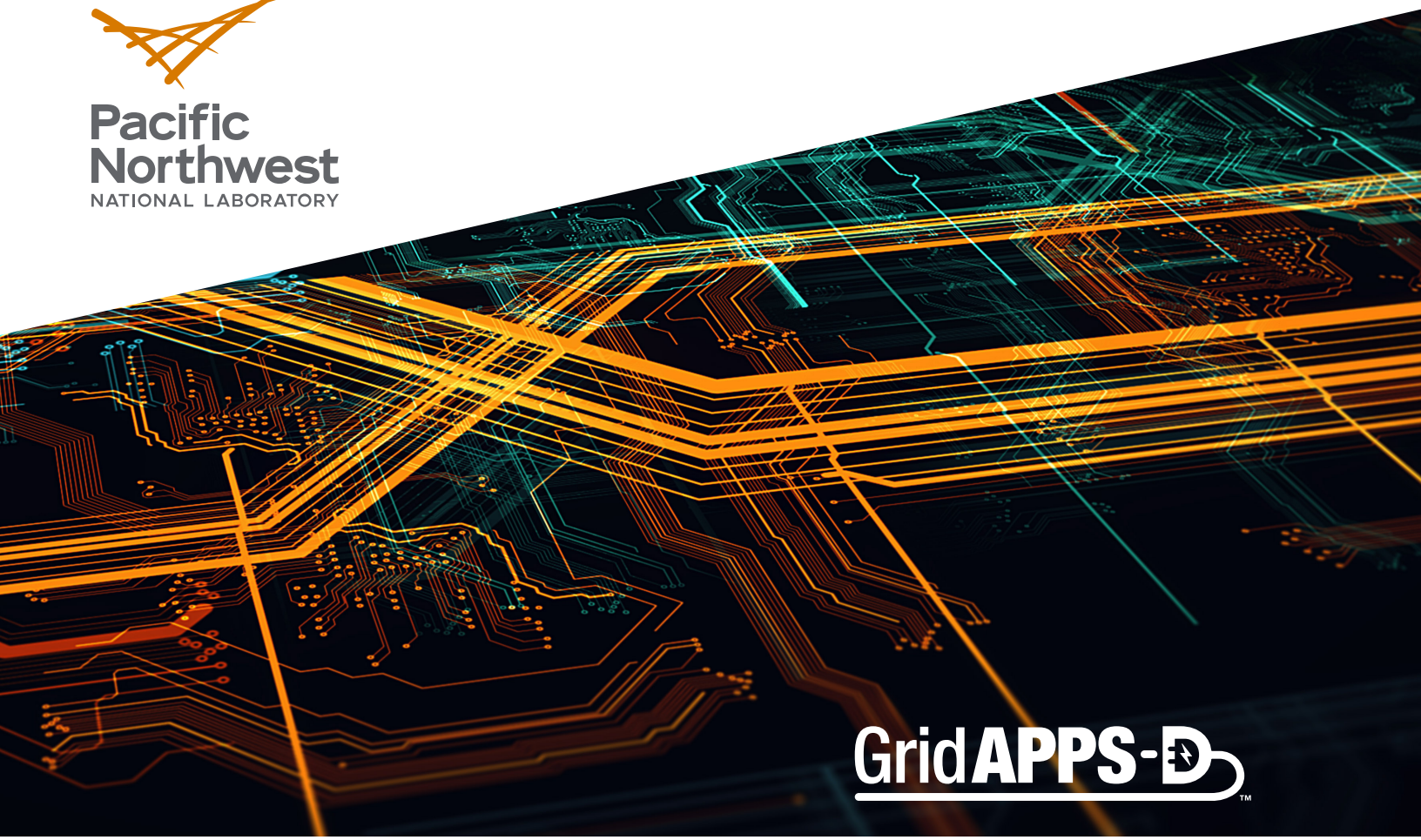

PNNL-29382

GridAPPS-D™ at Three: Milestones on the Road to Advanced Distribution Functionality

November 2019

Ronald B Melton
Tim Wolf

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Introduction

Scientists and engineers at Pacific Northwest National Laboratory (PNNL) have been working with their growing network of collaborators from industry and academia over the last three years to move the full vision of Advanced Distribution Management System (ADMS) functionality from PowerPoint slides and architectural diagrams to operational reality.

With sponsorship from the U.S. Department of Energy (DOE), the PNNL-led team has built a standards-based platform—GridAPPS-D—that separates data management and exchange processes from application functionality. The new platform removes barriers, enabling utilities to deploy robust, integrated ADMS capabilities.

Figure 1. Led by Pacific Northwest National Laboratory, the GridAPPS-D project team includes representatives from the national labs, academia, and industry, with team members from each executing to an integrated program management plan.

GridAPPS-D is an open-source software tool that's free to users. It has the potential to reduce the cost and complexity for utilities by adding new functionality to their distribution operations, while mitigating the myriad business challenges that come with siloed applications, proprietary systems, and custom interfaces. Over the past three years, the GridAPPS-D team has accomplished the following:

- established an industry advisory board of leading utilities, technology providers, and institutions to develop requirements and define use cases to guide platform and app development
- released the initial version of GridAPPS-D platform on GitHub in 2018 with ongoing enhancements and updates

- gathered requirements and begun development of an initial demo suite of GridAPPS-D-enabled applications that includes Volt-VAR optimization (VVO); transactive energy; demand forecasting; distributed energy resource (DER) dispatch; fault location, isolation, and service restoration (FLISR); and other situational awareness and grid management tools
- planned evaluation and testing programs in late 2019 for newly developed apps involving utility operators in a realistic grid operating environment
- engaged key industry standards groups—specifically CIM (Common Information Model) and MultiSpeak®—to ensure convergence of established industry standards in GridAPPS-D implementations and app development.

With these initial achievements, the GridAPPS-D team is now focused on building a robust ecosystem of platform users and app developers. As the GridAPPS-D platform matures and adoption increases, stewardship of the platform and ecosystem will be transitioned to an appropriate industry group.

GridAPPS-D: Origins and Industry Drivers

In February 2014, a group of experienced distribution system operators and engineers from leading utilities across the U.S. gathered in a conference room at CenterPoint® Energy in Houston for a DOE-sponsored “Voices of Experience” discussion on how they could take their operations to the next level.

Figure 2. The DOE-Sponsored 2014 Voices of Experience meeting, which gave utilities a forum to voice their challenges in implementing ADMS functionality, served as the key impetus for the GridAPPS-D project.

Enlivened by their recent experience implementing and evaluating new grid technologies funded by the federal Smart Grid Investment Grant Program, the operators and engineers wanted to share perspectives on how they could better integrate their systems and data to achieve business transformation. Specifically, this focused on eliminating paperwork and manual processes, making better use of real-time data from the grid, and automating many core distribution grid operations.

Thematically, of course, they were talking about ADMS, an integrated software platform that supports the full suite of distribution management and optimization applications. ADMS includes many functions that manage and respond to outages while optimizing the performance of the distribution grid. Core ADMS systems typically include Supervisory Control and Data Acquisition (SCADA); Outage Management; and advanced applications supporting use cases such FLISR, VVO, conservation voltage reduction, peak load management, management of microgrids, DER integration, and electric vehicles.

A Changing Business and Operational Environment

These utilities were responding to common and significant challenges. The utility business has been changing rapidly. At a time when customer expectations for quality service are higher than ever, electric utilities are facing an array of new challenges to delivering a reliable, affordable, and safe power supply. Increasing penetration of distributed energy resources—such as rooftop solar, electric vehicles, and energy storage systems—is creating new operational and planning headaches for grid operators. Grid operators must maintain continual balance between electricity supply and demand, ensure power quality, and protect expensive equipment amid two-way power flows, unprecedented load volatility, and rapidly changing conditions at the edge of the grid.

Adding to this complexity, grid operators are managing more and more intelligent, connected devices on the grid. These devices are creating a tsunami of data that must be collected, managed, secured, and applied to improve grid operations. In other words, managing the power grid is becoming a much more complex and data-intensive endeavor for all utilities.

Lessons Learned and Common Challenges

Though several of the utilities present at the Houston Voices of Experience meeting had begun implementing ADMS, a common challenge or obstacle soon emerged in the discussion. The cost and difficulties of data integration and exchange were delaying and diluting their business case benefits. Attaining the full ADMS functionality they envisioned was elusive. Nearly every utility present echoed this theme.

The group identified three key barriers to achieving advanced distribution capabilities: (1) the cost and complexity of integrating the various data systems, (2) the inability to evaluate and quantify operational benefits, and (3) the lack of a broad range of products that can address the needs of utilities of all sizes. Smaller rural electric cooperatives and municipal utilities have found it especially difficult to afford ADMS capabilities. There was also an internal issue that all the utilities had recognized—the lack of an accurate, maintained power system connectivity model that is necessary for ADMS systems to perform effectively.

ADMS comes at a cost, typically a seven-figure price tag for the software, and often five or six times the software's cost to integrate and implement it. In addition, data integration and interfaces are typically proprietary, locking the utility into the platform supplied by the ADMS vendor or requiring custom interfaces for applications from other suppliers, thus driving up integration costs and complexity. As a result, utilities find it difficult to pursue a "best-of-breed" approach to acquire applications from a variety of vendors to meet their specific use-case requirements.

Taking Action

In 2016, DOE's Office of Electricity took these lessons learned at the Voices of Experience meeting and sponsored a project to develop a solution that simplifies and reduces the costs of implementing ADMS capabilities. The project was initially funded and chartered through the Grid Modernization Laboratory Consortium, a group of 13 national laboratories working collaboratively on projects that span a broad array of grid modernization domains.

The objective of the project was to create an open-source technology platform that enables power distribution software applications to be developed for any compliant system instead of just one. Providing a common platform for application development will do the following:

- reduce costs to develop, integrate, and maintain future applications
- improve distribution system reliability
- simplify and accelerate system planning and operations research and development within DOE labs and industry
- define and establish common interface standards for the platform and the applications to make it easier to integrate best-of-breed applications.

The Value of GridAPPS-D

- **For utilities**, GridAPPS-D will reduce integration time and cost because the apps and platform are standards-compliant. It allows standardization of the data exchange interfaces between multi-vendor devices and applications, whether they are running at the grid edge in the utility control room, or somewhere in between. Utilities can purchase portable, "best of breed" apps from any source, choosing only those that meet their needs. And utilities can switch out or upgrade functionality more easily and with reduced costs as needs change.
- **System vendors** benefit from GridAPPS-D because they can offer products that help their utility customers reduce time and cost to deploy apps in their operations, increasing customer satisfaction. This platform also enables them to deliver their applications to ADMSs developed by other vendors, creating a potential for increased market penetration.
- **Application innovators** benefit by developing portable apps that can be used by multiple vendors and utilities. These apps can be deployed with minimal customization on any vendor's system, and with the open source environment, more opportunities are available for smaller innovators and startups and in-house utility developers.
- **For the research community**, GridAPPS-D helps reduce costs with its open-source environment, while providing a common testing tool that allows comparison of results from different applications under different operating and performance scenarios.

Introducing the GridAPPS-D Platform

Developed by PNNL and its network of industry collaborators, GridAPPS-D has emerged as the solution to these industry challenges. GridAPPS-D provides utilities, their vendors, application innovators, and researchers with a common software platform that delivers standardized operational technology integration, enabling accelerated development and deployment of portable applications for power distribution planning and operations.

Fundamentally, GridAPPS-D separates the data collection and integration function from application functionality, shifting the distribution applications ecosystem away from proprietary, vertically integrated architectures to an open, layered, and standards-based architecture. Like Apple's iOS or Google's Android platform for smart phone apps, the GridAPPS-D platform supports integrated access to data and enables app development and deployment to make the nation's power grid more resilient, efficient, and flexible.

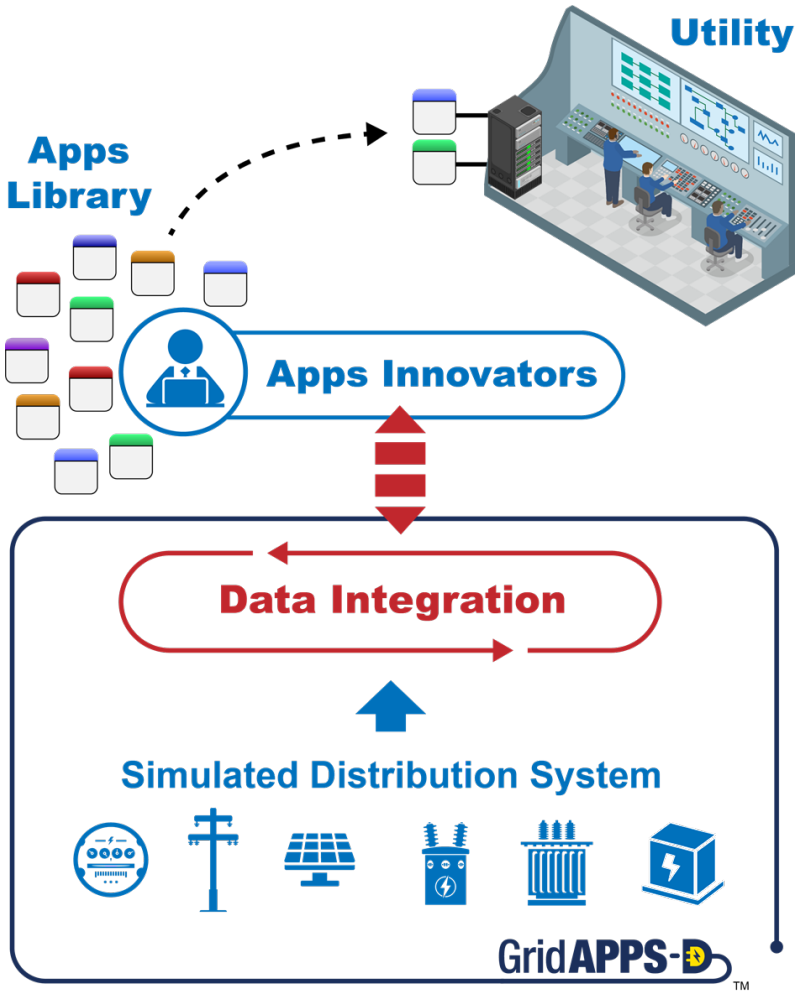

Figure 3. An open-source, open-architecture platform streamlines development and implementation of advanced distribution applications by separating data integration from app functionality.

GridAPPS-D is the first platform for energy and distribution management systems that is designed with standards for data integration, including data models, programming interfaces,

and data exchange interfaces between grid devices in the field, distributed applications in utility systems, and applications in utility control rooms. This means that the applications developed using GridAPPS-D make them broadly applicable and interchangeable across utility systems, reducing the cost and time for utilities to integrate new functionality.

The First Three Years of GridAPPS-D

Since the project's inception in 2016, the GridAPPS-D team at PNNL has worked closely with its partners in industry and academia—as well as its advisory board of leading utilities—to develop the platform and the supporting resources. Here are some of the milestones, highlights, and achievements during the first three years of the project that set the stage to mature the platform and establish a robust GridAPPS-D ecosystem to realize and share the benefits more broadly among utilities.

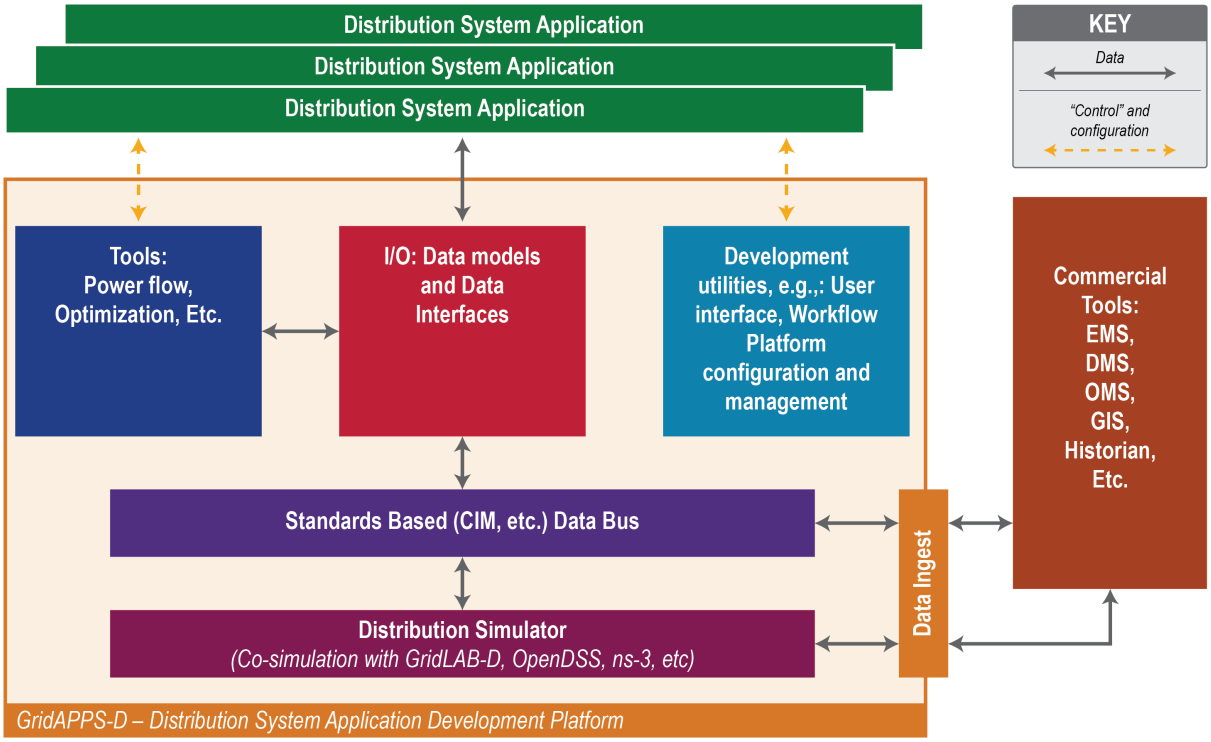

Figure 4. The innovative architecture of GridAPPS-D separates the data collection and integration function from distribution application functionality, shifting the applications ecosystem away from proprietary, vertically integrated architectures to an open, layered, and standards-based architecture.

Year One

The first year of the project was spent developing various project documents, establishing an industry advisory board (which met for the first time in February 2017), and executing the first release cycle for the platform.

The project management plan was created along with the statement of project objectives. The functional requirements, conceptual design (PNNL-26340; Melton et al. 2017), and statement of

system concept were created, along with developing the interoperability standards work plan. A Software QA Plan was also created for the platform and ADMS applications.

The team created a validation plan describing the overall approach to verify the benefits of the ADMS platform. The ADMS State of the Industry and Analysis Gap (PNNL-26361; Agalgaonkar et al. 2016) was completed along with the GridAPPS-D Evaluation Framework A Systems Engineering Approach (PNNL-26362; Sanquist and Schneider 2017). The team also engaged with various industry standards committees. Release Cycle 1 Integrated Implementation Plan was created, data store schema was designed, a messaging framework was selected, and one language binding was selected and implemented.

Year Two

During the second year of the project, project documents were updated, Release Cycles 1 and 2 were completed, and Release Cycle 3 was started.

Project documents that were updated include the Project Management Plan, the Software QA Plan, and the Working Document Implementation Plan. A transition plan was also completed during year two. The Industrial Advisory Board held quarterly meetings throughout year two. Team members made presentations, submitted papers to journals and conferences, and held work group meetings. During year two, RC1 and RC2 were completed, and significant progress was made on RC3.

The initial release of GridAPPS-D was made available on GitHub in 2018. The GridAPPS-D team has also developed a suite of example applications to demonstrate the use of the platform based on actual data from operational smart-grid technologies and systems.

Year Three

During year three, a new version was released for GridAPPS-D, software was demonstrated to the Industrial Advisory Board, and team members attended various conferences and working group meetings to build the ecosystem. In addition, applications were prioritized for beta testing and platform integration testing.

The Industrial Advisory Board met quarterly throughout year three. At the May meeting, software was demonstrated from the recently completed release cycle 3 of GridAPPS-D V1.0. Release Cycle 4 added many enhancements to better support application development and integration.

Application development continued in parallel with platform development in year three.

Four applications were prioritized for beta version completion and platform integration testing: State Estimation, PNNL; VVO, PNNL; DER Dispatch, National Renewable Energy Laboratory; and Resilient Distribution Restoration with high-DER penetration, Washington State University. The team also prepared for the application evaluation by modifying and testing the 8500 node model, while also preparing for implementation of the 9500 node distribution feeder model, which provides a CIM-compliant operational model with switches, loads, DERs, and a potential microgrid, enabling developers to test their work and compare results using a common data model. The GridAPPS-D website (gridapps-d.org) was rolled out. The foundational paper on GridAPPS-D was submitted and accepted to IEEEAccess, an online, open-access, peer-

reviewed journal. App developers wrote papers describing their algorithms, and some have been published in journals.

Figure 5. The GridAPPS-D Industry Advisory Board brings together leading utilities, smart grid technology vendors, and industry associations to guide platform and application development.

Before the end of 2019, the GridAPPS-D applications and the platform itself will be evaluated by utility industry users to assess the benefits of advanced applications. Feedback from this evaluation will enable the application innovators to make their example applications more useful to industry while engaging more stakeholders about the value of the platform.

The Path Ahead: Evolution toward an ‘OT Bus’

Looking forward, emphasis will be placed on extension of the platform to support distributed applications and field deployment and trials. There are also ongoing activities that strengthen the tie to standards, including needed extensions to CIM and incorporation of MultiSpeak and 61850. Finally, execution of the plan for transition to industry continues.

A significant barrier to utilities realizing the value of advanced distribution management applications is the lack of standardized data exchange between the growing ecosystem of connected devices in the field and applications that create value from their data, whether those apps are running in the cloud, the control room, or at the edge of the network. This barrier increases the costs and complexity for utilities to add new capabilities to their distribution operations while also limiting their choice of technology providers.

GridAPPS-D provides testing tools and applications, robust simulation capabilities, a reference architecture, and application development kit. In the simplest of terms, the GridAPPS-D platform

provides functionality to utilities that can be best described as an “OT Bus,” providing simplified and robust data transfer capability among an array of grid operational technologies. The platform standardizes the data models, data exchanges, and programming interfaces for these devices and applications, accelerating the development, integration, and adoption process.

GridAPPS-D breaks down the silos between systems, enabling vendors to innovate and utilities of all sizes to add new functionality to meet the significant challenges they face in building and operating a modernized grid. The next three years will move GridAPPS-D from the development stage toward implementation, working with industry to gather requirements, define use cases, and test and validate applications.

References

Agalgaonkar Y.P., M.C. Marinovici, S.V. Vadari, K.P. Schneider, and R.B. Melton. 2016. *ADMS State of the Industry and Gap Analysis*. PNNL-26361. Richland, WA: Pacific Northwest National Laboratory.

Melton, R., K. Schneider, T. McDermott, and S. Vadari. *GridAPPS-D Conceptual Design, V1.0.* PNNL-26340. Richland, WA: Pacific Northwest National Laboratory

Sanquist T.F., and K.P. Schneider. 2017. *Grid-APPS-D Evaluation Framework: A Systems Engineering Approach*. PNNL-26362. Richland, WA: Pacific Northwest National Laboratory.

IEEE Access Paper:: https://doi.org/10.1109/ACCESS.2018.2851186

https://github.com/GRIDAPPSD/

Pacific Northwest National Laboratory

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99354
1-888-375-PNNL (7665)

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