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GridAPPS-D Conceptual Design

V1.0

May 2017

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U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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GridAPPS-D Platform		
Version	Date	Comments
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1.1 Introduction

The purpose of this document is to provide

- A conceptual design of the distribution system application development platform being developed for the U.S. Department of Energy's Advanced Distribution Management System (ADMS) Program by the Grid Modernization Laboratory Consortium project GM0063.
- The platform will be referred to as GridAPPS-D.

  This document provides a high level, conceptual view of the platform and provides related background and contextual information. This document is intended to both educate readers about the technical work of the project and to serve as a point of reference for the project team. The document will be updated as the project progresses.

1.1.1 Need for open platforms, and a standards based approach

Through a series of industry centric meetings and workshops, the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability (DOE-OE) gathered input from utilities throughout the United States on their experiences in implementing, or planning to implement, ADMS. The results of these meetings are documented in a report titled "Voices of Experience: Insights into Advanced Distribution Management Systems[1i]" published in February 2015.

The report documents the potential benefits to utilities in implementing ADMS systems, and underscores the need for more affordability, a timely path for

[1] U.S. Department of Energy, February 2015, "Voices of Experience: Insights into Advanced Distribution Management Systems", accessed March 2017 at: https://energy.gov/sites/prod/files/2015/02/f19/Voices%20of%20Experience%20-%20Advanced%20Distribution%20Management%20Systems%20February%202015.pdf

deploying ADMS, and the development and deployment of new and updated ADMS applications. The high cost and amount of time required for ADMS deployment and application development was highlighted.

In response to these needs, DOE-OE has established an ADMS program with this project specifically tasked with "Developing an open-source, standards based distribution system application development platform." This project and the related projects in the program are described in the ADMS Multi-Year Program Plan[ii].

1.1.2 What is a platform?

To better understand the nature of this project, it is useful to explain what is meant by the term "platform." It is quite common in today's electric power industry to hear the term platform. Vendors often describe their suite of products in terms of a platform or collection of platforms. Regulators, for example in New York, talk about elements such as a "distribution system platform provider." In more common use consumers are faced with choices of platform for smartphones, such as Apple's iOS™ and Google's Android platforms. So, what is a platform in the context of the ADMS program and the development distribution system applications?

For the purposes of GridAPPS-D, we use the term platform in the sense of a software platform.

- A software platform provides an environment within which applications may be run, and in our case developed and tested.
- The platform requires well-defined interfaces, enabling functionality, interoperability, testing, and some form of user interaction.

  In the case of GridAPPS-D, this conceptual design provides a high-level description of a platform for developing distribution system applications; applications developed by a wide range of stakeholders for use in a wide range of system sizes, conditions and architectures.

- Thus the platform includes
  - standardized data models and application programming interfaces to support data needs of distribution system applications;
  - supporting computational utilities such as optimizers and power flow calculators with well-defined interfaces;
  - underlying distribution system simulation capabilities;
  - functionality directed towards application development including tools needed to support application development, for example versioning;
  - functionality available to test these applications under different system, functional, and performance conditions;
  - and the ability to configure the platform according the context of the application under development.

1.1.3 Provide reference point for industry evolution

The intent of this work is to provide a point of reference of the electric power industry that demonstrates the quantifiable benefits of an open platform, standardized approach, and the benefits of data rich distribution system applications. The approach is intended to be vendor neutral, and applicable to utilities of all sizes and structure.

The standardized nature of the approach is intended to

- create the opportunity for an distribution system application developer to create their application within a compliant, standardized instantiation of the platform and have the application be able to be deployed with minimal customization on any vendor’s ADMS or other platform that is also compliant.
- If successful, this will provide both new opportunity for vendors to focus their efforts on the value added nature of their distribution system applications and for utilities to purchase “best of breed” applications from any source.
- The end goal will be to shift the cost associated with expensive ADMS deployments from integration issues, to functions that provide the utility with quantifiable operational benefits.

The results of this effort will be an open-source reference implementation accompanied by a documented reference architecture and design such that they can be used by the industry in new product development or modification of existing products. In support of this approach industry standards will be used to the greatest extent possible. To validate the utility of the GridAPPS-D platform, a small number of distribution system applications will be developed by the project team, and tested and evaluated by utility dispatchers/operators.

1.1.4 Structure of this document

This document is organized into the following sections:

- **Purposes of the GridAPPS-D platform -** a summary of the motivations for developing this software
- **General requirements -** a listing of general requirements to be met while developing the software for this platform
- **Conceptual architecture -** an annotated diagram showing the major functional elements and their interactions and interconnections
- **Platform functional elements -** a more detailed description of each of the major functional elements

1.2 Purposes of the GridAPPS-D Platform

There are multiple purposes for the GridAPPS-D platform work. This section of the conceptual design summarizes these purposes to provide context for development and subsequent use of the platform.

1.2.1 Distribution system application development

The fundamental purpose of the efforts of this project is to create a distribution system application development platform: GridAPPS-D. Distribution system application developers such as commercial vendors, utilities, research organizations, and educational institutions will use this platform to develop new and innovative applications. Distribution system application developers will be creating an application to solve a specific problem related to planning and/or operation of electric power distribution systems. These applications use data originating in Supervisory Control and Data Acquisition Systems (SCADA), smart grid devices, and systems deployed in the distribution system. The data can include system measurements and metadata about the devices, systems, the electricity delivery network and the business processes and objectives of the utility.

1.2.2 Support development of new applications for modernized grid

In providing support for distribution system application development, GridAPPS-D will include capabilities for applications that will be needed in the near-term to 15-year time frame. These applications may or may not be substantially different than those needed in the immediate future. In particular, they will have to address increasing levels of distributed energy resource (DER) penetration in distribution systems, transition from centralized control to distributed or hierarchical control, incorporation of distributed sensors and sensor networks, the introduction of markets in distribution systems, the entry of new players into the marketplace such as aggregators or microgrid operators and for some utilities an evolution from a role as electricity provider to service provider or other modifications to the business model.

1.2.2.1 Increasing levels of DER penetration

A key driver for change in electricity distribution networks is increasing penetrations of DER. As discussed in De Martini and Kristov (2015)[1], increased DER penetration requires changes in both the business and operational models of distribution utilities. In their business models, utilities face challenges with cost-recovery and the ability to account for new interactions and services associated with DER. For example, deployment of transactive energy systems may require new metering or other measurement

[1] "Distribution Systems in a High Distributed Energy Resources Future: Planning, Market Design, Operation and Oversight," prepared for the U.S. Department of Future Electric Utility Regulation project by Paul De Martini and Lorenzo Kristov, October 2015. Accessed March 2017 at: https://emp.lbl.gov/sites/all/files/FEUR_2%20distribution%20systems%2020151023_1.pdf

capabilities to account for the transactions. Operationally, distribution system dispatchers face voltage control and optimization problems with high penetrations of distributed photovoltaics, possibly new peak loads with uncoordinated charging by increasing numbers of electric vehicles, and additional challenges from increased deployment of customer or grid-scale storage systems.

1.2.2.2 Distributed controls

One response to the operational challenges and effective integration of increased levels of DER, especially customer owed DER, is a shift from centralized control system to decentralized or distributed control systems. These systems will require different types of operator surveillance and situational awareness. In addition, they may move system operation to be more forward looking by, for example, having improved forecasting capabilities.

1.2.2.3 Distribution (retail) markets

As mentioned above, deployment of transactive energy systems or other market based constructs to facilitate DER integration could be increasingly important as the level of DER penetration grows (see again De Martini and Kristov (2015).) These markets will, at a minimum, require new tools for market oversight and operation. They may also be thought of as a form of smart grid application and represent an example of a class of distribution system applications. The New York REV is taking a leadership role in this effort through the introduction of Distribution System Platform Provider (the distribution equivalent of the ISO) focused on providing retail market, grid operations and planning services to a broad range of entities that include the incumbent utility and other stakeholders. Other states including California, Minnesota, Hawaii and the District of Columbia are actively considering similar transformations.

1.2.2.4 Introduction of new actors in the distributed marketplace.

The introduction of DERs into the utility grid is also bringing with it, the potential for increased independence of the customers with respect to their dependence on the grid and the amount of energy they consume from the grid. With this new independence, new players are seeing an opportunity to service this change in the customer-base and their new or existing needs that require new applications and or new interactions. These new players include aggregators (who can collect groups of customers and create a new class of customers and provide more opportunity to them away from just being a consumer of electricity), and microgrids that can take a group of mostly contiguous customers and attempt to provide more of their energy needs locally. They may also be thought of as a form of smart grid application and represent an example of a class of distribution system applications.

1.2.2.5 Distribution utility as a service provider

With increasing levels of customer self-supply leading in some cases to "net-zero" residences and buildings, the role of the utility may change from one of energy supplier to that of a service provider. For example, most net-zero installations still require energy supply because they are net-zero on average. The utility becomes provider of a storage service when excess energy is produced and a supply service when it is needed. This perspective changes both the business and operating requirements for the utility and will require new distribution system applications. Whatever the future distribution utility structure looks like, the GridAPPS-D platform must be capable of supporting development of applications for their environment.

1.2.3 Provide a reference implementation and architecture for an open, standards based platform

The results of this effort are intended to provide a vendor independent and neutral implementation of a platform using an open architecture, standards based approach. All work will be completed as open source, so that stakeholders can use the completed platform, or any portion of it that they find useful for their development needs.

1.2.4 Move the industry towards an open, standards based platform approach

By providing an open-source implementation of an advanced distribution system application development platform, with a documented design and reference architecture, the GridAPPS-D project results are intended to motivate adoption of such an approach within the industry. This will shift the focus of software development from protecting closed architectures, to a more collaborative open architecture, enabling a greater array of advanced distribution system applications to be developed by a broader set of application developers. The results are expected to increase opportunity for both traditional system vendors and new application developers through enabling applications to be developed that will easily run in multiple vendor environments. This is not intended to be competitive to existing vendors but allow the ones that are compliant with GridAPPS-D to become more competitive than others due to their ability to be better able to handle new value-added applications fully integrated within their environments.

1.2.5 Demonstrate the value of advanced distribution system applications

The value of ADMS is presumed to be through the access to broader sets of data, databases, and controls providing the ability to perform more actions in an automated manner and moving the utility personnel from working on just doing things to identifying, predicting and acting. The data sources are available from a complete set of back-office systems, an accurate and up-to-date power system connectivity model and information enabled (“smart”) technology deployed throughout the distribution system and possibly from related infrastructures. This is in contrast to current systems such distribution management systems (DMS), outage management systems (OMS) and others that tend to be stove-piped systems drawing on limited data sources to solve a specific problem.

The GridAPPS-D platform will be used to develop data rich distribution system applications that will be evaluated through side-by-side comparison with conventional applications such as OMS, CVR, and FLISR. These comparisons will involve utility dispatchers operating these tools in an environment that is familiar to people with an operational background.

1.3 General Requirements

General requirements are those requirements that are to be met in implementing a system due to customer requirements or other considerations. As a part of the definition of the ADMS Platform project or to take advantage of prior U.S. DOE investments there are several such requirements.

1.3.1 Vendor / Vendor platform independent

The platform is intended to be independent of any specific vendor or vendor platform, in other words vendor neutral. The results of this effort are intended to be useful and available to any vendor or application developer who wishes to apply them or incorporate them into existing or future products.

1.3.2 Standards based

To the greatest extent possible the system should incorporate and support industry standards, in particular interoperability standards, including the Common Information Model, ISO/IEC 61850, the open field messaging bus (OpenFMB), MultiSpeak(TM) and others as they are useful. Gaps in the existing standards will be explicitly identified, steps to close the gap developed, and extensions proposed back to the standards development organizations.

1.3.3 Replicable

As a reference implementation, architecture and design, the results should be replicable. A first level of demonstration of this will be that the system can be deployed at multiple locations. The next level of demonstration of replicability is independent implementation based on the reference implementation, architecture and design with demonstrated ability to move an application from one system to the other.

1.3.4 Flexible distribution simulator

The distribution simulator will be able to use an appropriate mix of simulation tools. Given the prior U.S. DOE investment in GridLAB-D, it will be used for the distribution simulator and other functionality such as power flow calculations to the extent that it meets the application development requirements.

1.3.5 Applicable to utilities of all sizes and business / operational models

To the greatest extent possible, the results will be applicable to utilities or all sizes and business and operational models.

1.4 Conceptual Architecture

A conceptual architecture for the system has been developed as shown in the figure below. The key features of this architecture are fully described in the next section of this design.

1.4.1 Platform functional elements

GridAPPS-D has five key functional elements. The figure below is the conceptual architecture showing the relationship between these functional elements. The figure also shows the relationship between GridAPPS-D and the application developer and the relationship to commercial tools. Two different classes of data flow are shown. "Control" and configuration data enabling the application developer to manage the platform are shown with dashed lines. Data flowing as a part of an application are shown with solid lines.

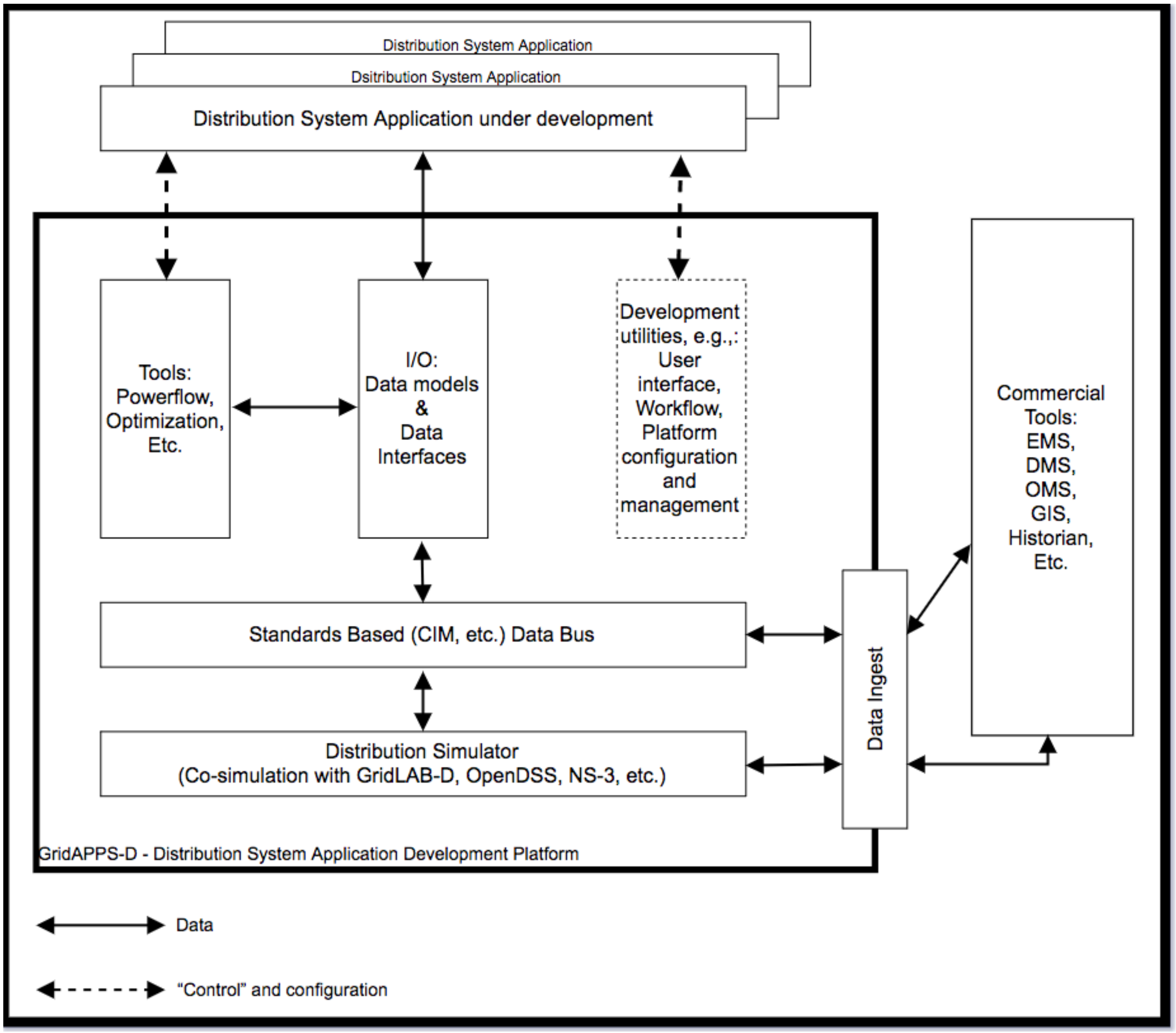

Figure 1: GridAPPS-D Conceptual Architecture

The next four sections summarize the expected functionality of the platform. The two data functional elements are combined into one section. This is followed by discussion of utilities available to the application developer, support for application development, and lastly the distribution simulator.

1.4.2 Data representation and management

A key to GridAPPS-D is providing the distribution system application developer with a standardized approach to data. The intent is to allow the developer to make logical references to data referencing standard data models and interfaces without concern for how the data is physically made available. This standardized, logical data interface will be based on existing standards to the greatest extent possible.

1.4.2.1 Standards based data representation

Existing standards such as IEC61968-11 (IEC TC 57, WG14 common information model (CIM) document on systems interfaces for distribution management systems), MultiSpeak®, IEC 61850, and OpenFMB™ will be applied to develop common, standards based data models and representations.

- The CIM provides a standardized means of describing the structural model of an electric power system and the messages exchanged between the elements of the system.
- IEC 61850 standardizes substation automation and data flows between the intelligent end devices and the substation, and between the substation and the control center.
- OpenFMB is a framework and reference architecture comprised of existing standards that enables grid edge interoperability and distributed intelligence, augments operational systems, and enhances integration with field devices.
- MultiSpeak is a standard for enterprise application interoperability.

It should be noted that in general these standards are still evolving.

1.4.2.2 Standard data model

Building on the use of evolving standards such as the distribution CIM, we will create standard data models that will be used as an underpinning part of every part of the platform.

1.4.2.3 Standard data interfaces

From the standard data models, we will define standard data interfaces. This is how we intend to enable the distribution system application developer to work with logical data references.

1.4.2.4 Data translation to non-standardized elements

Given that much of the data in existing systems has not been acquired and stored using a standards based approach, data translation will be required to ingest data into the platform and to provide data from the platform to related systems.

1.4.3 Standardized utilities

The distribution system application developer will need access to standardized utilities to support the application. GridAPPS-D must offer a standardized interface to a useful set of such utilities.

1.4.3.1 Commonly needed utilities available

Commonly used utilities are expected to include those listed below. There may be other types of utilities that will be useful that will be identified either during requirements definition for the platform or at a later date.

- Distribution power flow
- Optimizers
- Others will be included as they are identified

1.4.3.2 Standard process for incorporating new utilities

Given that we can reasonably expect that additional utilities will be needed over time, a standard process for integrating new utilities will be needed. This must address how the utility is invoked within an application, how data is transferred into and out of the utility and how it is managed and configured.

1.4.4 Distribution simulator

A special class of utility is the distribution simulator. The distribution simulator is the source of data to the distribution system application developer enabling them to evaluate the performance of their application with ideal or realistic data under different operating and performance conditions. Considerations for the distribution simulator are listed below.

1.4.4.1 Representative distribution system

The distribution simulator must have a representative distribution system as its basic model. This model must be configurable with in a range of topology and other options. We anticipate, for example, having a simulator with a combination of radial and meshed distribution feeders with the ability to specify which (or a combination) should be used. We also anticipate the need to integrate with existing utility distribution models to have the capability to run the platform on real utility models and to be able to include different types of DER's, microgrids, and their interconnection devices such as smart inverters.

1.4.4.2 "Real-time" operation

To support distribution system application development we also require "real-time" operation. The application developer needs to be able to work with the data dynamically, in particular when developing the user interface and other visual elements of an application. There is also a need for being able to simulate SCADA data, AMI/meter data and other data with fine temporal resolution with the simulator providing an experience similar to what would be found in the field at a utility.

1.4.5 Application development support

As a distribution system application development platform, GridAPPS-D must include the tools for the developer to "program" an application. This includes at least three key elements: user interface development, application workflow (or logic) programming, and configuration of the development environment. Each of these is discussed in more detail below.

1.4.5.1 Application User Interface development

Distribution system applications will often require graphical user interfaces both for using the application and for visualizing the results of the applications logical processing of data. GridAPPS-D will provide a basic operating interface for the application developer. The developer will be responsible for the user interface of the application. In the future, GridAPPS-D may be extended or related work undertaken to accommodate advances in computing technology for displays and for visualization techniques.

1.4.5.2 Application workflow

The logical functionality of a distribution system application may be thought of as a workflow within which modules function in a controlled sequence of operations. Tools supporting the identification of data sources, the algorithmic and logical processing steps associated with deriving value from the data will be required. Included in this is the ability to easily include the functionality of the standardized utilities mentioned above.

1.4.5.3 Environment configuration

To support application development, the GridAPPS-D user will require the ability to manage the development environment. This includes being able to configure and use the distribution simulator, the ability to configure and use the standardized utilities, and the ability to manage the application development process.

Distribution

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[ii] "Advanced Distribution Management System (ADMS) Program – Multi-year Program Plan 2016 – 2020," August, 2016, U.S. Department of Energy, Office of Electricity Delivery and Energy Reliabiltiy. Access online https://www.smartgrid.gov/files/ADMS_MYPP_20160824_DRAFT.pdf

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