Enabling Evaluation of a Southern Company Distribution Feeder on NREL ADMS Test Bed

Cooperative Research and Development Final Report

CRADA Number: CRD-17-00674-6

NREL Technical Contact: Ismael Mendoza Carrillo

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated under Contract No. DE-AC36-08GO28308

Technical Report
NREL/TP-5D00-93384
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NOTICE

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Cooperative Research and Development Final Report

Report Date: February 10, 2025

In accordance with requirements set forth in the terms of the CRADA agreement, this document is the CRADA final report, including a list of subject inventions, to be forwarded to the DOE Office of Scientific and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

Parties to the Agreement: Southern Company Services, Inc.

CRADA Number: CRD-17-00674 (Project 3 of 4, Modification 6)

CRADA Title: Enabling Evaluation of a Southern Company Distribution Feeder on NREL ADMS Test Bed

Responsible Technical Contact at Alliance/National Renewable Energy Laboratory (NREL):

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Sponsoring DOE Program Office(s): U.S. Department of Energy, Office of Electricity

Joint Work Statement Funding Table showing DOE commitment:

No NREL Shared Resources

Estimated Costs	NREL Shared Resources a/k/a Government In-Kind
Year 1	$.00
TOTALS	$.00

Executive Summary of CRADA Work:

The objective of this project is to enable evaluation of a Southern Company distribution feeder on the Advanced Distribution Management System (ADMS) test bed. The long-term goal is to evaluate a federated distributed energy resource (DER) management solution that aggregates DERs through either direct control, transactive control or an aggregator to provide bulk services while observing distribution system voltage and power constraints. The DER aggregation needs to be coordinated with an ADMS that is responsible for reliable power delivery across the distribution systems. This project takes the first step towards enabling such evaluation by deploying an ADMS from Oracle (Southern Company's ADMS supplier) with a Southern Company feeder at NREL.

CRADA benefit to DOE, Participant, and US Taxpayer: Assist laboratory in achieving programmatic scope.

Summary of Research Results:

Phase 1. The scope of this CRADA encompasses the set-up and configuration of an Oracle ADMS at NREL with a Participant's feeder.

NREL TASKS:

Task 1. Deploy an Oracle ADMS that includes the Oracle Network Management System at NREL.

The NREL team was able to successfully deploy the required network environment to install the Oracle ADMS in collaboration with both Oracle and GridBright. Oracle's Network Management System (NMS)[1] is a software platform environment that utilities can leverage as a vehicle to enable various applications for real-time monitoring of the distribution grid for enhanced visibility, and for control to ensure the optimization of power delivery and to increase resiliency. The NMS standard platform consists of a series of distributed servers to support the overall operation for each service. Each server hosts a dedicated service for modular configuration. Figure 1 shows an overview of an NMS network diagram. The database server hosts the utility data models, system configuration, and historical operation data. The Application Server's purpose is to host and run enterprise applications with a native application programming interface (API) providing a gateway to exchange information with the entire environment. Live Energy Connect provides a protocol converter as a gateway for utilities to bridge real-time communication to their operational network with field devices, database servers, or higher-level controllers using standard utility protocols such as ICCP, Modbus, and DNP3. The NMS server provides a graphical user interface service for the end user to monitor and operate a desired service area. Once the environment was set up, the NMS's configuration was validated with the included synthetic network model before loading the partner data.

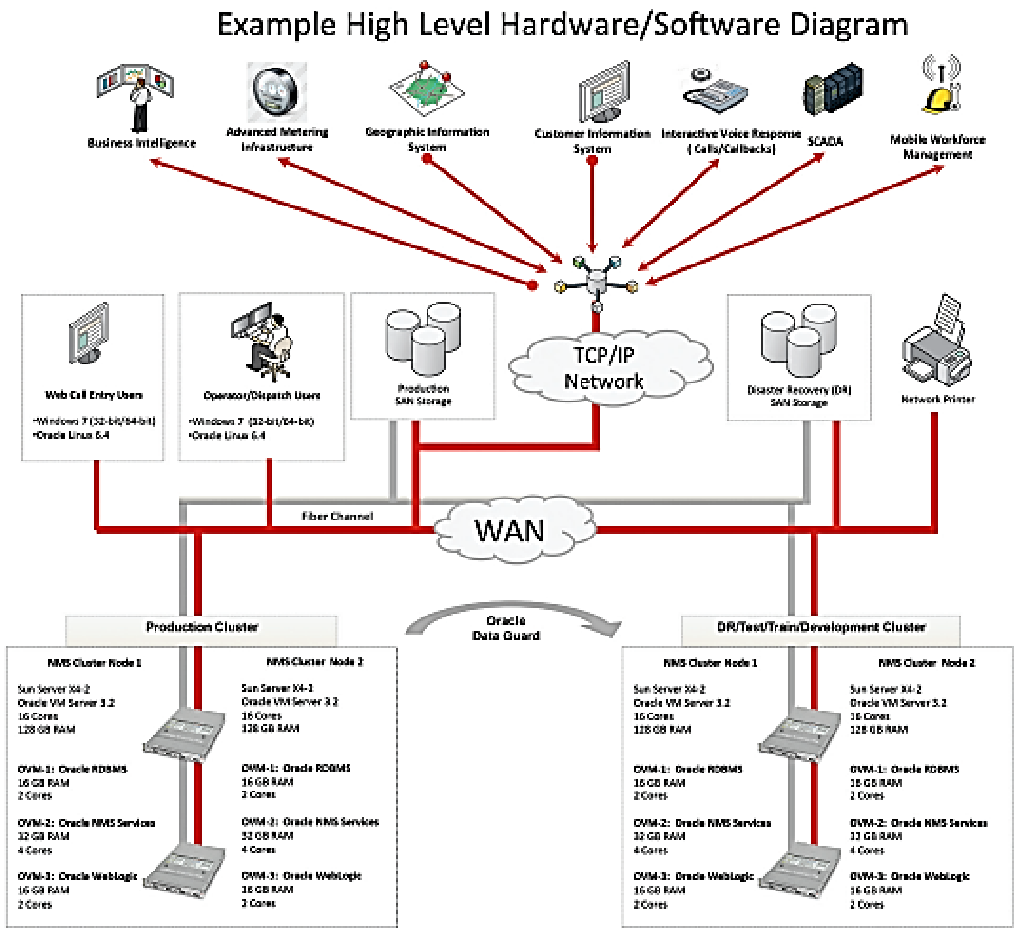

Figure 1.Overview of an example NMS Installation Network Diagram Source: Oracle NMS Configuration Guide V2.5.1.5 February 2022[2]

Task 2. Load Participant's feeder data into the ADMS.

NREL, GridBright, and Oracle worked collaboratively to load the feeder information into NREL's NMS environment. The Southern Company provided the entire network database of the evaluation substation to GridBright to incorporate the schema modification and LEC mapping for interoperability with the hardware capabilities in the ADMS Test Bed. There was a version discrepancy in the NMS database version provided by the Southern Company to the version installed at NREL. A database upgrade from NMS version 2.3 to 2.5 was the initial step. Once upgraded, the database was loaded to the NMS system revealing additional feeders and control zones outside the scope of this project. GridBright took the task to reduce the database and remove interdependencies to the single feeder that is part of this evaluation. The new schema was securely transmitted to NREL and successfully loaded in the ADMS Test Bed environment. Once the system was installed, a signal end-to-end verification was performed to evaluate adequate communication with the ADMS Test Bed. Figure 2 shows an image of the evaluation feeder in the Oracle NMS environment at NREL's ADMS Test Bed.

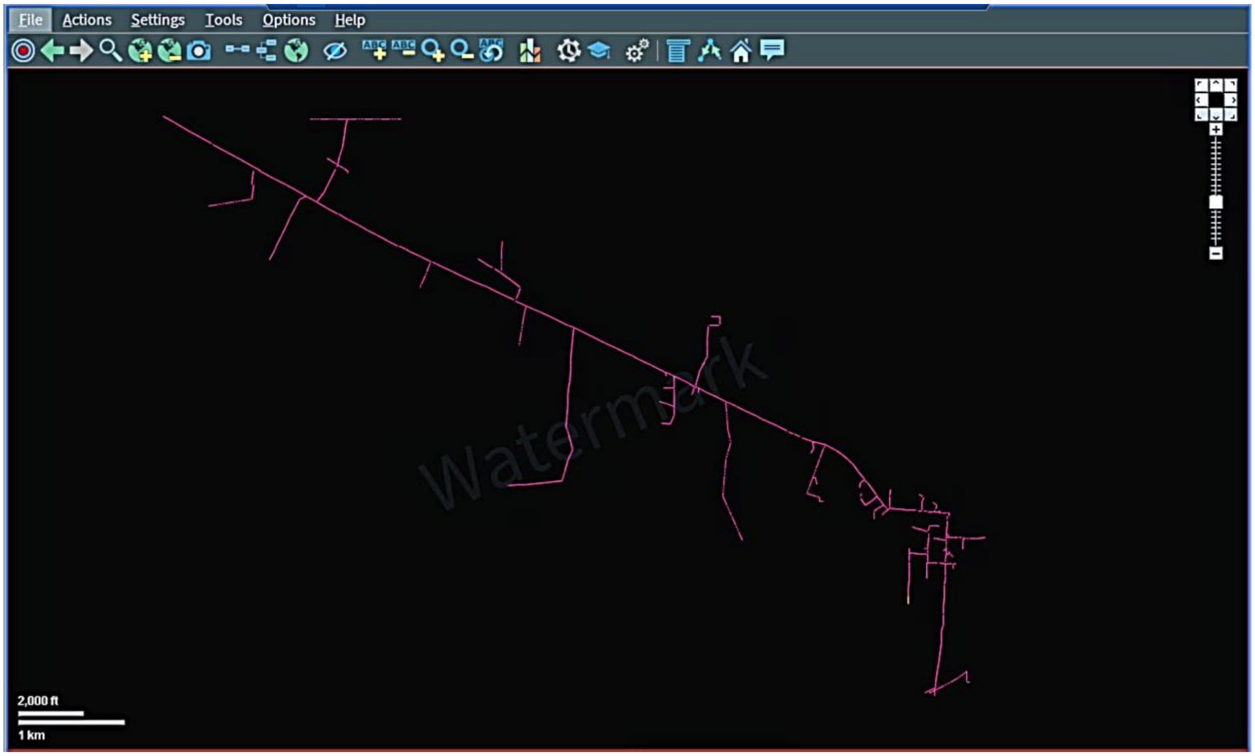

Figure 2. Evaluation Feeder in the Oracle NMS Enviroment

Task 3. Add DERs, as agreed upon with Participant, to the feeder model in the ADMS.

The long-term objective is to demonstrate the reduction of reverse power flow from excessive DER power generation with the controls developed under the FAST-DERMS project [3]. To achieve the objective, the controller should have direct control of three hypothetical utility-scale BESS. NREL evaluated the load profile of the feeder and the expected photovoltaic (PV) generation from the existing utility-scale PV systems to identify the locations of the BESS. These BESS locations were presented to the utility partner. The partner agreed on the locations of the simulated BESS to assist in the evaluation of the implementation of reverse power flow control. Figure 3 illustrates the placement of the three different utility-scale BESS in the evaluation feeder.

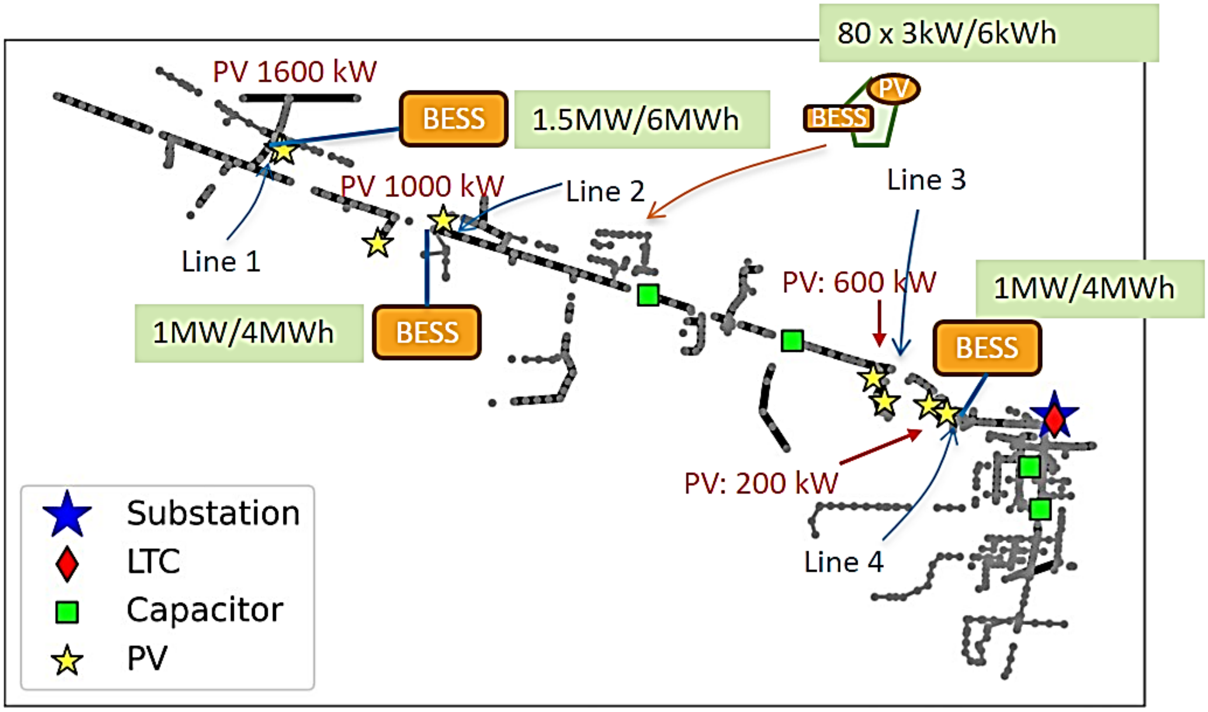

Figure 3. Diagram indicating the proposed location for the Utility Scale BESS

Task 4. Verify that power flow results from the ADMS match data provided by the Participant.

The partner provided a feeder from their service territory for the evaluation. The initial network model was supplied in Eaton's CYME [4] distribution system software. The feeder contained over 200 loads with an energy demand of 4.4 MW. Additionally, the system contains nine utility-scale PV systems with a total generation of 3.7 MW. The model is equipped with four capacitor banks and a load tap changer (LTC) for voltage regulation assistance. To use the model in the NREL ADMS Test Bed, NREL leveraged the Distribution Transformation Tool [5] (DiTTo) to convert the model from CYME to EPRI's OpenDSS [6] quasi-static time series power distribution system simulator. The converted model power flow and voltage profile were validated against the furnished CYME model.

The PV systems were disabled for all the power flow studies. The initial configuration contained all capacitor banks enabled and an LTC center set point of 123.5 volts. Figure 4 display the voltage profile for the CYME model in blue and the OpenDSS model in orange. From the image it can be observed that the trend for both models is consistent and the minimal offset in the OpenDSS profile is an artifact of the line parameters' conversion. The voltage disparity was quantified to +/- 0.6% for the entire network as seen in Figure 5. The voltage profile can be seen to surpass the ANSI C84.1[7] standard upper tolerance of 1.05 p.u. because all the capacitor banks were closed during this process of the evaluation. The power flow assessment provides a 0.08% and 2.7% difference for real power and reactive load power respectively between the two models, as shown in Table 1.

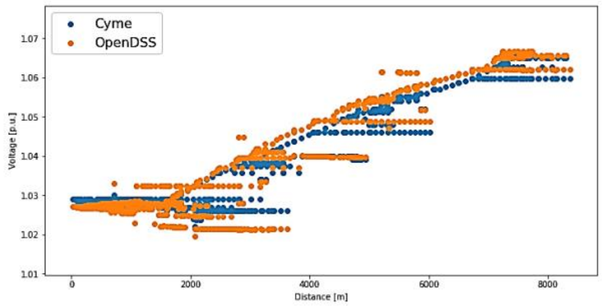

Figure 4. Feeder Voltage Profile Comparison with 123.5V LTC set point

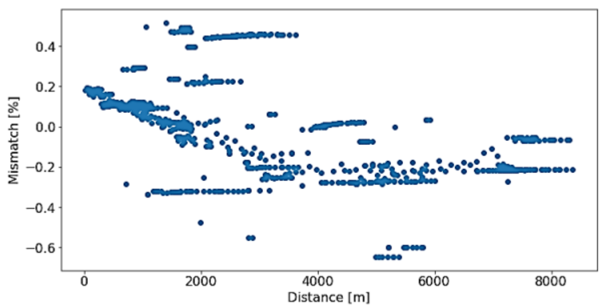

Figure 5. Feeder Voltage Profile Node Voltage Mismatch with 123.5V LTC set point

Table 1. CYME and OpenDSS Feeder Power Flow Validation Results with 123.5V LTC set point

Total Load kW			Total Load kVAR		
CYME	OpenDSS	Error	CYME	OpenDSS	Error
4447.0	4443.6	0.08%	2232.8	2292.3	2.7%

A second evaluation was performed with the four capacitor banks disabled and the LTC set point at its neutral position of 120V. The voltage profile trend and percent node voltage difference between the CYME and OpenDSS models were comparable to the previous results. Figure 6 and

Figure 7 display the results with the new equipment configuration. By comparing Figure 6 to Figure 4, the impact of disabling the capacitor banks and lowering the LTC set point can be observed. Table 2 exhibits the power flow results for the evaluation with a slight impact in the CYME results with the new equipment configuration. The power flow results comparison between the two models resulted in 0.6% and 3.5% difference for real power and reactive power respectively.

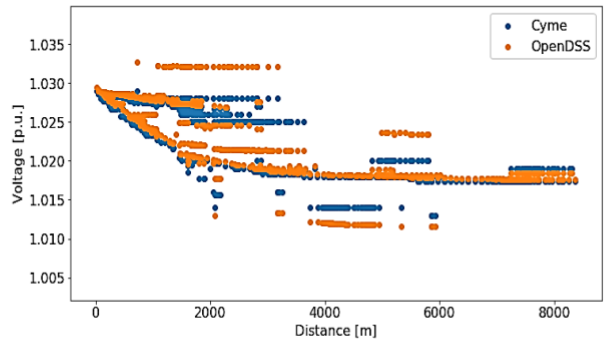

Figure 6. Feeder Voltage Profile Comparison with 120V LTC set point

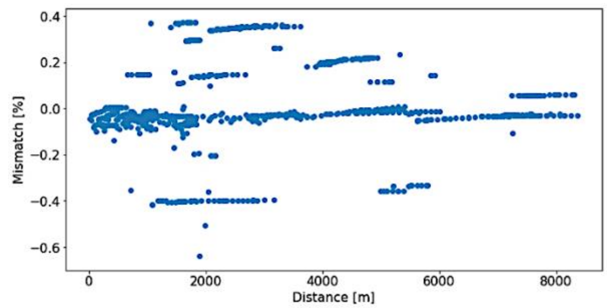

Figure 7. Feeder Voltage Profile Node Voltage Mismatch with 120V LTC set point

Table 2. CYME and OpenDSS Feeder Load Conversion Power Flow Validation Results with 120V LTC set point

Total Load kW			Total Load kVAR		
CYME	OpenDSS	Error	CYME	OpenDSS	Error
4469.3	4442.7	0.6%	2212.0	2289.4	3.5%

The final step in the power flow validation was to compare the OpenDSS converted feeder model results with the Oracle ADMS power flow results. The ADMS has a study session mode capability that enables the system to run specific scenarios for evaluation. The ADMS system load flow operates based on annual studies providing a generic representation of the load variety of the specific feeder. During normal operations the ADMS facilitates seasonal changes by implementing a scale factor to the load profile demand based on real-time field data. The power flow study mode load scenario was configured to run a static load set to the peak load on a clear, warm, weekday profile with a load profile scaling factor of 4.6 to achieve similar load demand as used for the CYME to OpenDSS comparison.

During the ADMS power flow study the LTC was maintained in its neutral position, matching the second evaluation between OpenDSS and CYME because it kept the feeder voltage close to nominal, which prevented the capacitor banks from injecting reactive power. The real and reactive power comparison between the ADMS and the OpenDSS and CYME models are presented in Table 3.

Table 3. ADMS and OpenDSS Feeder Load Power Flow Validation Results with 120V LTC set point

Total Load kW			Total Load kVAR		
ADMS	OpenDSS	Error	ADMS	OpenDSS	Error
4432	4442.7	0.25%	930	2289.4	59.3%
ADMS	CYME	Error	ADMS	CYME	Error
4432	4469.3	0.83%	930	2212.0	57.95%

The real power differences were 0.25% and 0.83% showing that the real power load representation in the ADMS is very similar to both the OpenDSS and CYME simulated models. The reactive power on the other hand has a difference of 59.6% and 57.95%, indicating that the load reactive power in the ADMS is based on a power factor closer to unity. As previously indicated, the ADMS system can update the power factor dynamically, based on real-time field data, and apply a power factor to the load profiles that result in more closely matched reactive power demand.

Task 5. Perform other associated work as needed, consistent with the scope and subject to the availability of funding.

Collaborate with Oracle and GridBright through a series of meetings to successfully deploy the environment at NREL. Attended quarterly update meetings with participant an convey tasks updates.

Task 6. Prepare and submit CRADA Final Report in accordance with Article X.

This final report meets the requirement for this task.

PARTICIPANT TASKS:

Task 1. Provide agreed-upon feeder data to be loaded into ADMS system via secure method.

The participant provided the agreed feeder data that was loaded to the ADMS system as per NREL's task 2.

Task 2. Provide agreed-upon field data to be used for verification via secure method.

Participant provided the agreed-upon field data that was used for the verification in NREL's task 4.

Task 3. Evaluate power flow verification results and provide feedback to NREL in team meeting and/or in response to e-mail correspondence.

Participant provided feedback in the model conversion and validation thorough teams meetings

Task 4. Perform other associated work as needed, consistent with the scope and subject to the availability of funding.

Participant attended quarterly meeting and provided input to NREL's tasks 2, 3, and 4.

Task 5. Collaborate as needed with NREL on the preparation of the CRADA Final Reporting accordance with Article X.

Participant collaborated with NREL in the preparation of the CRADA final report in accordance with Article X.

References:

[1] Oracle NMS overview https://www.oracle.com/industries/utilities/products/advanced-distribution-management-system/ visited July 15, 2022

[2] Oracle NMS Configuration Guide https://docs.oracle.com/cd/F41370_07/PDF/NMS_V2_5_0_1_5_Configuration_Guide.pdf

[3] FAST-DERMS https://gmlc.doe.gov/projects/2.1.1

[4] CYME https://cyme.com/software/BR917001EN-CYME-software.pdf

[5] DITTO https://nrel.github.io/ditto/

[6] OpenDSS https://www.epri.com/pages/sa/opendss

[7] ANSI c84.2 https://webstore.ansi.org/Standards/NEMA/ANSIC842020?source=blog&_ga=2.154986680.1680571147.1658767134-850380115.1658767134 visited July 20, 2022

<u>Subject Inventions Listing</u>:

None

<u>ROI #</u>:

None