

Commonwealth Energy Biogas/PV Mini-Grid
Renewable Resources Program

***Making Renewables Part of an Affordable and
Diverse Electric System in California***

Contract No. 500-00-036

**Develop Three BI-PV & Biogas High-Penetration
Scenarios on Two Feeders**

Project No. 3.1 Dairy Waste to Energy

Task 3.1.9b Draft Final Report

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California Energy Commission
Public Interest Energy Research - Renewables Program

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Table of Contents

1 Introduction	1-1
1.1 PIER Program Overview	1-1
1.1 Commonwealth Program Overview.....	1-2
1.2 Purpose of Detailed Interconnection Study	1-2
1.3 Organization of Report	1-3
2 High-Penetration Scenario and Feeder Selection Development Overview	2-1
2.1 Goals and Objectives	2-1
2.2 Intended Results	2-1
3 High-Penetration Renewable DG Scenarios and Feeder Selection.....	3-1
4 C9 Main Feeder and Laterals Description.....	4-1
5 D6 Main Feeder and Laterals Description.....	5-1
6 High-Penetration BI-PV and Biogas Renewable DG Scenarios.....	6-1
Appendix A	A-1
Appendix B.....	B-1

List of Figures

Figure 3-1: Commerce Energy Mini-grid Distribution Systems	3-3
Figure 4-1: C9 Main Feeder Configuration without Renewable DG - Peak MW and MVAR Flows.....	4-2
Figure 4-2: C9 Lateral Sections A and E Configuration without Renewable DG - Peak MW and MVAR Flows	4-3
Figure 4-3: C9 Lateral Section B Configuration without Renewable DG - Peak MW and MVAR Flows	4-4
Figure 4-4: C9 Lateral Section C Configuration without Renewable DG - Peak MW and MVAR Flows	4-5
Figure 4-5: C9 Lateral Section D Configuration without Renewable DG - Peak MW and MVAR Flows	4-6
Figure 4-6: C9 Lateral Section F Configuration without Renewable DG - Peak MW and MVAR Flows	4-7
Figure 5-1: D6 Main Feeder Configuration with Peak MW and MVAR Flows.....	5-2
Figure 5-2: D6 Lateral Sections A and B Configuration with Peak MW and MVAR Flows.....	5-3

Figure 5-3: D6 Lateral Sections C and D Configuration with Peak MW and
MVAR Flows.....5-4

List of Tables

Table 6-1: Feeder C9 Renewable Penetration Scenarios (MW).....6-2
Table 6-2: Feeder D6 Renewable Penetration Scenarios.....6-3
Table A-1: Expanded C9 Feeder and Lateral Database..... A-1
Table B-1: Expanded D6 Feeder and Lateral Database..... B-1

1

Introduction

1.1 PIER Program Overview

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally beneficial, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings' End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

For more information on the PIER Program, please visit the Energy Commission's Web site at: <http://www.energy.ca.gov/research/index.html> or contact the Energy Commission's Publications Unit at 916-654-5200.

For Commonwealth/Commerce Energy Program-specific information, please visit <http://www.pierminigrid.org>.

Presented here is a report for the California Energy Commission, Public Interest Energy Research Program, Contract Number 500-00-036, conducted by the Commerce Energy (formerly Commonwealth Energy) Team.

1.1 Commonwealth Program Overview

In June 2001, the Commerce Energy Team was awarded a programmatic contract under the California Energy Commission's Public Interest Energy Research (PIER) Program to conduct research on strategies for making renewable energy more affordable in California. The Commerce Energy approach involves assessing the combined potential of biogas and photovoltaic (PV) resources in a defined study area and identifying how these resources could be developed in a complementary and cost-effective manner. The Commerce Energy Team conducted this research in a real world setting so that the findings could be applied elsewhere in California and thereby benefit more California ratepayers. The local area that Commerce Energy selected for its renewable energy research activities is the Chino Basin, referred to in this report as the "mini-grid area."

The Chino Basin is rich in PV and biogas renewable resources. Moreover, it is a rapidly growing area with substantial and increasing electrical loads. The underlying goal of the Commerce Energy PIER Renewables Mini-grid Program is to identify potential Building Integrated PV (BI-PV) and biogas energy projects, bring innovative technologies and business practices to these projects, assess the benefit to the local electricity distribution system (the "mini-grid"), and then use the findings to develop a business model for siting cost-effective, renewable energy projects. A description of the Commerce Energy PIER Program, including the results of some of the work undertaken to date, is presented in the program's Web site, <http://www.pierminigrid.org>.

1.2 Purpose of Detailed Interconnection Study

As part of the program planning and analysis performed under Project 1.1, information on the local transmission/distribution system was collected in Task 1.1.6, and a power flow study to identify and quantify the benefits of renewable energy projects on the local electric distribution system were performed under Task 1.1.9.

The results of this power flow study were reviewed at the Program Planning and Analysis (Project 1.1) Critical Project Review (CPR) meeting. The results indicated that there were no "show stoppers" for the *expected case*, *high* and *low* biogas and BI-PV generation penetration scenarios studied in this project. In addition, further detailed studies in the following areas were recommended to supplement these power flow study results and help to ensure successful operation of the mini-grid (and other distribution systems) with significant penetration of distributed generation on the feeders:

- A detailed interconnection study (e.g., Task 3.1.9) that considers relaying requirements, integrated control of distribution system voltage, reactive power

scheduling, communication requirements and short circuit duty impacts with high penetration levels of biogas and BI-PV distributed generation installed.

- A dynamic study of the transient response of high penetration levels of biogas and BI-PV distributed generation to disturbances on nearby feeders or substations (e.g., Task 3.1.10) to test the stability of the distributed generation during appropriate transient events.

1.3 Organization of Report

This report presents the results of Task 3.1.9b - describing the two selected feeder characteristics and associated three high-penetration renewable generation scenarios to be used in the interconnection study. Section 2 presents the goals, objectives and intended results. Section 3 describes the high-penetration scenario and distribution feeder selection procedure. Section 4 presents the main feeder and lateral configuration for Feeder C9. Section 5 presents the main feeder and lateral configuration for Feeder D6. Section 6 describes the high-penetration BI-PV and biogas renewable penetration scenarios developed for the two selected feeders.

2

High-Penetration Scenario and Feeder Selection Development Overview

2.1 Goals and Objectives

The objective of Task 3.1.9 is to perform a detailed interconnection study to evaluate potential impacts of pertinent interconnection requirements and issues for three potential high-penetration PV and Biogas incremental generation scenarios on two selected distribution feeders. The detailed interconnection study will consider relaying requirements, integrated control of distribution system voltage, reactive power scheduling, communication requirements and short circuit duty impacts with high penetration levels of the biogas and BI-PV distributed generation (DG) installed.

The goal Task 3.1.9b is to develop plausible high-penetration renewable scenarios that are compatible with the selected feeder characteristics and results of the previous mini-grid power flow study described within the Planning and Analysis Project Task 1.1.6 and 1.1.9 reports.

The objective of Task 3.1.9b is to develop three appropriate potential high-penetration renewable DG scenarios and select two feeders to examine the expected range of potential interconnection requirements and issues identified in Task 3.1.9a. The high-penetration scenarios are to include a high biogas DG penetration scenario, a high BI-PV penetration scenario, and a high *combined* BI-PV and biogas DG scenario. Three plausible high-penetration renewable DG scenarios are to be employed on two distribution feeders with different characteristics. One feeder with primarily underground construction and one feeder with primarily overhead construction are to be selected to examine potential interconnection requirements for different feeder characteristics.

2.2 Intended Results

The intended result of Task 3.1.9b is to develop a task report describing the two selected feeder characteristics and associated three high-penetration renewable DG scenarios to be used in the detailed interconnection study under Task 3.1.9c.

3

High-Penetration Renewable DG Scenarios and Feeder Selection

The Commerce Energy mini-grid distribution systems are illustrated in Figure 3-1. The high-penetration renewable DG scenario resulting from the mini-grid market potential study is 54.1 MW within the mini-grid by the Year 2012. The allocation of this DG capacity is approximately 39 MW of BI-PV and 15.1 MW of biogas generation. The bulk of the BI-PV penetration occurs in the northern portion of the mini-grid, within distribution substation service areas (see Figure 3-1) B, C, F, and G, which serves a large amount of commercial and industrial loads. The biogas penetration occurs at three wastewater treatment plants located in distribution substation service areas D, I and U in the mini-grid area. In addition, a biogas generator is located at a closed landfill located in distribution substation service areas F to represent potential landfill biogas applications in open landfills in other areas outside the Commerce Energy mini-grid.

Distribution systems B, C, F, and G have BI-PV high-penetration scenario assumptions for Year 2012 in the mini-grid power flow study of more than 4 MW, 6 MW, 9 MW and 6 MW respectively. In the previous mini-grid study, the BI-PV generation is assumed to be distributed throughout the distribution system feeders as described in the mini-grid study reports. Note that three feeders in the above distribution systems, (i.e., feeders C7, C9 and F3) contained the heaviest BI-PV market penetration - all with more than 1 MW of BI-PV.

High renewable DG feeder penetration levels ranging from approximately 6 to 8 MW is assumed for this detailed interconnection study. These feeder renewable penetration levels are compatible with the mini-grid distribution system BI-PV penetration levels described above. First, these higher feeder penetration levels may occur if it is assumed that the BI-PV penetration is concentrated on a few feeders serving commercial and industrial loads rather than distributed over several feeders. Second, Year 2012 is now only six years out. Thus, given the heavier emphasis on renewable generation in state policy, over the next 5 to 10 years higher penetrations may occur than originally forecast in the mini-grid market potential study.

Distribution systems D and F biogas penetration assumptions for Year 2012 in the high-penetration scenario in the mini-grid power flow study are more than 5 MW and 7 MW, respectively. These biogas generators in distribution systems D and F are located at two large

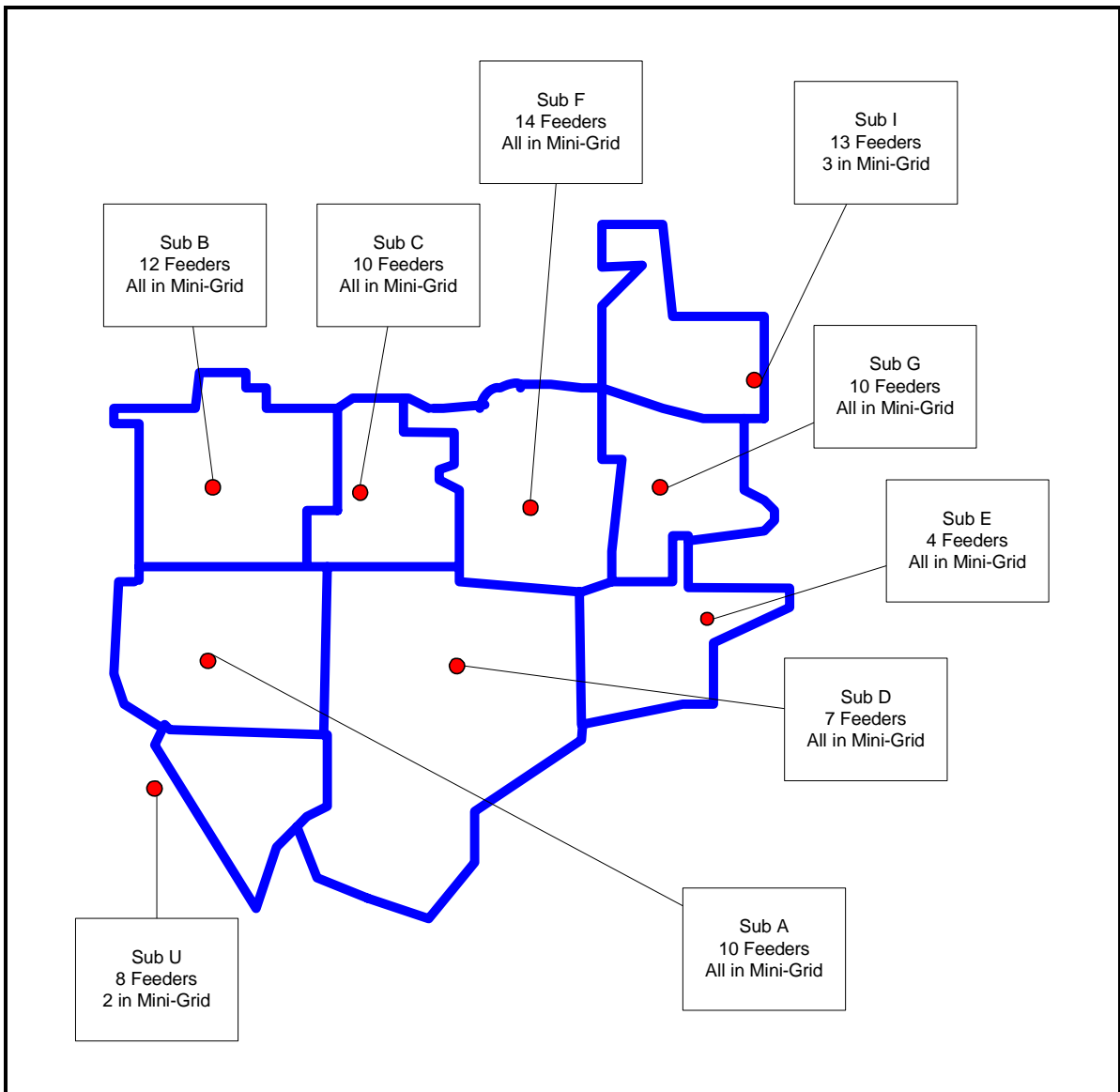
MW-scale plants. Thus the 6 MW to 8 MW feeder renewable penetration levels are also consistent with the mini-grid feeder biogas penetration levels considered in the mini-grid market potential study.

Feeder C9 has been selected as one of the feeders for the detailed high-penetration interconnection study. There are five reasons this feeder was selected for the study. First, it is located in the heart of the upper portion of the mini-grid where the highest penetration levels of BI-PV are expected to occur over the next ten years. Second, it consists of primarily underground construction and is heavily loaded in the 2012 timeframe. Third, it serves commercial and industrial customers, and contains more than 50 potential locations for BI-PV at customer locations served by the C9 laterals. Fourth, in the mini-grid power flow study, the C9 feeder contained one of the highest BI-PV penetration levels in the mini-grid -- by the Year 2012 high penetration scenario Feeder C9 will have over 1 MW of BI-PV. Finally, Feeder C9 serves customers near the RP-1 wastewater treatment plant where MW-scale biogas generation is currently employed, and it could be connected to the RP-1 biogas generation.

Feeder D6 was selected as the second feeder for the detailed high-penetration interconnection study. First, it serves the RP-1 wastewater treatment plant where MW-scale biogas generation is currently employed. Second, in the mini-grid power flow study, the D6 feeder contained one of the highest biogas generation penetration levels in the mini-grid by the Year 2012 high penetration scenario - over 5 MW of biogas generation. Third, it has different characteristics than Feeder C9. Feeder D6 consists of primarily overhead construction, contains residential as well as commercial and industrial customers, and is relatively lightly loaded compared to Feeder C9 in the 2012 timeframe.

Note that Feeder C7 may also be considered as an alternate to Feeder C9 for sensitivity analysis to study any pertinent overhead vs. underground construction impacts where appropriate in this study. It is also located in the heart of the upper portion of the mini-grid where the highest penetration levels of BI-PV are expected to occur over the next ten years. Feeder C7 is also heavily loaded like Feeder C9 in the 2012 timeframe. It also serves commercial and industrial customers. It also contains more than 50 potential locations for BI-PV at customer sites served by the C7 laterals, and the lateral configuration is similar to the C9 laterals. In the mini-grid power flow study, the C7 feeder also contained over 1 MW of BI-PV market penetration. The main differences between Feeders C9 and C7 are that the C7 main feeder consists primarily of overhead construction rather than underground construction, and Feeder C7 is not located near any biogas generation plants.

Figure 3-1: Commerce Energy Mini-grid Distribution Systems



4

C9 Main Feeder and Laterals Description

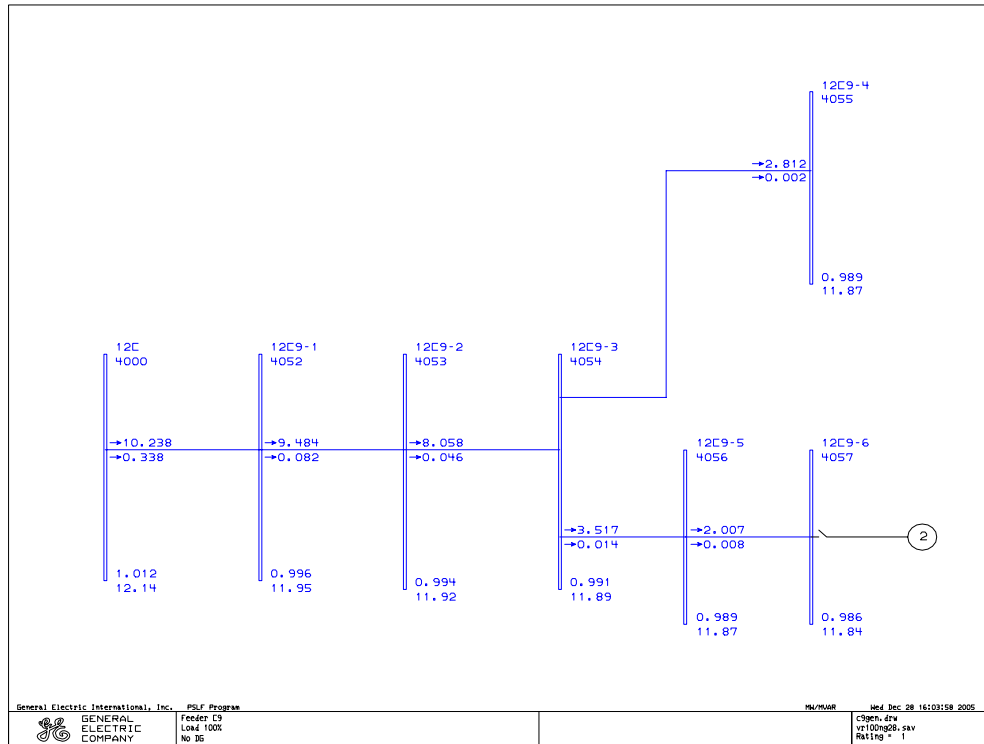
Laterals serving commercial and industrial loads were added to the main C9 12 kV feeder representation to illustrate the number of potential BI-PV locations, size and places where BI-PV will be installed on the distribution circuit, as described further later in this report. This more detailed distribution circuit representation will be used for demonstrating some calculations in this high-penetration interconnection study, such as feeder breaker - lateral fuse coordination, where applicable, and for the dynamic modeling in Task 3.1.10.

The C9 circuit is assumed to be heavily loaded, similar to the feeder loading for 2012 in the mini-grid power flow study, serving a total peak load of 10 MW at the load busses located throughout the circuit. The total C9 12 kV circuit was expanded to include the main feeder plus six lateral sections serving more than 50 commercial and industrial load points designated as Lateral Sections A through F.

The main feeder electrical configuration is shown in Figure 4-1. This is the same C9 (main) feeder configuration used for the mini-grid power flow study, as described in the Task 1.1.6, Task 1.1.9a and Task 1.1.9b final reports. Bus 4000, named 12C is located at Substation C, and the other busses have the same numbers and names as described in the report.

MW and MVAR flows during peak load conditions in each of the main feeder branches during peak feeder load conditions without renewable DG are shown in Figure 4-1. Bus 4057 contains one potential generation location for a biogas generator, (identifier no. 2) for the high-penetration scenarios to be described later. No load points are shown on the main feeder, as the loads have all been moved to locations in the C9 laterals described later. The electrical characteristics for the main feeder and all the lateral branches are presented in Appendix A, Table A-1.

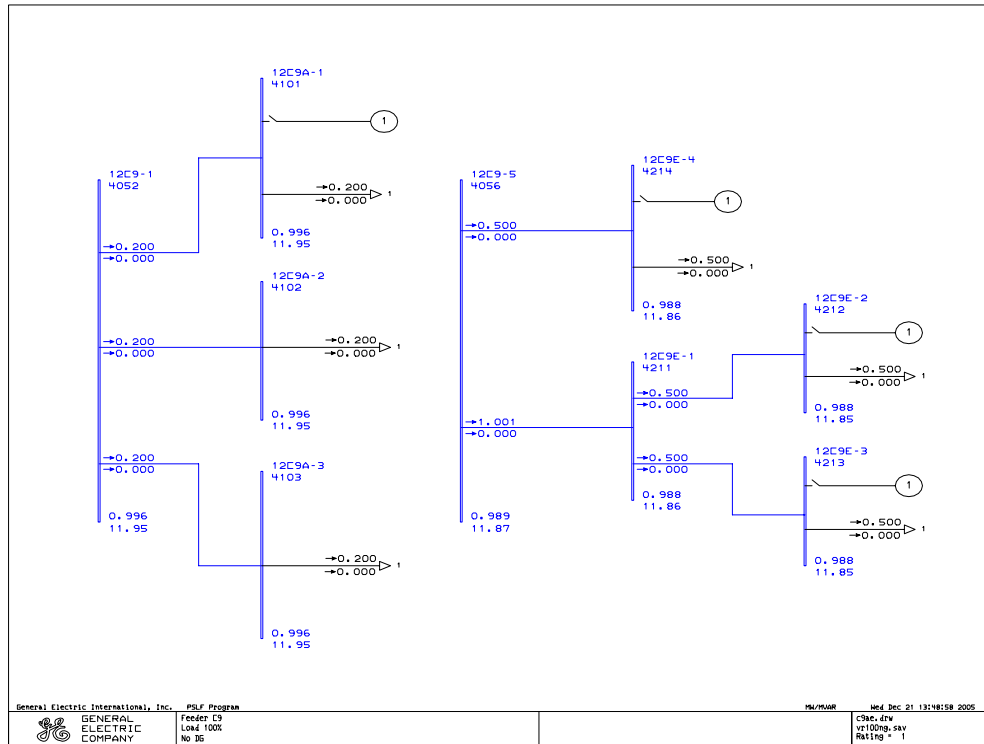
Figure 4-1: C9 Main Feeder Configuration without Renewable DG - Peak MW and MVAR Flows



The electrical configuration for lateral sections A and E are shown in Figure 4-2. Lateral section A connects to Bus 4052, named 12C9-1 located on the main feeder, and the other busses in Section A have names including the lateral section letter as shown in the Figure. Lateral section E connects to Bus 4056, named 12C9-5 located on the main feeder, and the other busses in Section E have names including the lateral section letter as shown in the Figure.

MW and MVAR flows during peak load conditions in each of the Section A and E branches during peak feeder load conditions and without renewable DG are shown in Figure 4-2. Busses 4101, 4212, 4213 and 4214 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

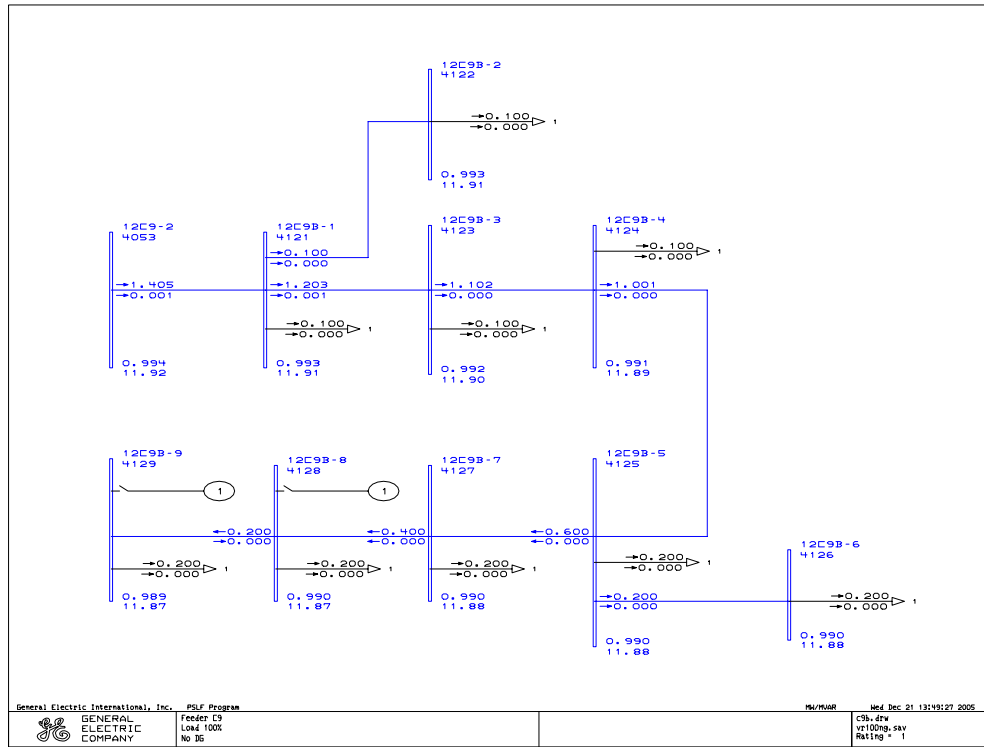
Figure 4-2: C9 Lateral Sections A and E Configuration without Renewable DG - Peak MW and MVAR Flows



The electrical configuration for C9 lateral section B is shown in Figure 4-3. Lateral section B connects to Bus 4053, named 12C9-2 located on the main feeder, and the other busses in Section B have names including the lateral section letter as shown in the figure.

MW and MVAR flows during peak load conditions in each of the Section B branches during peak feeder load conditions and without renewable DG are shown in Figure 4-3. Busses 4128 and 4129 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

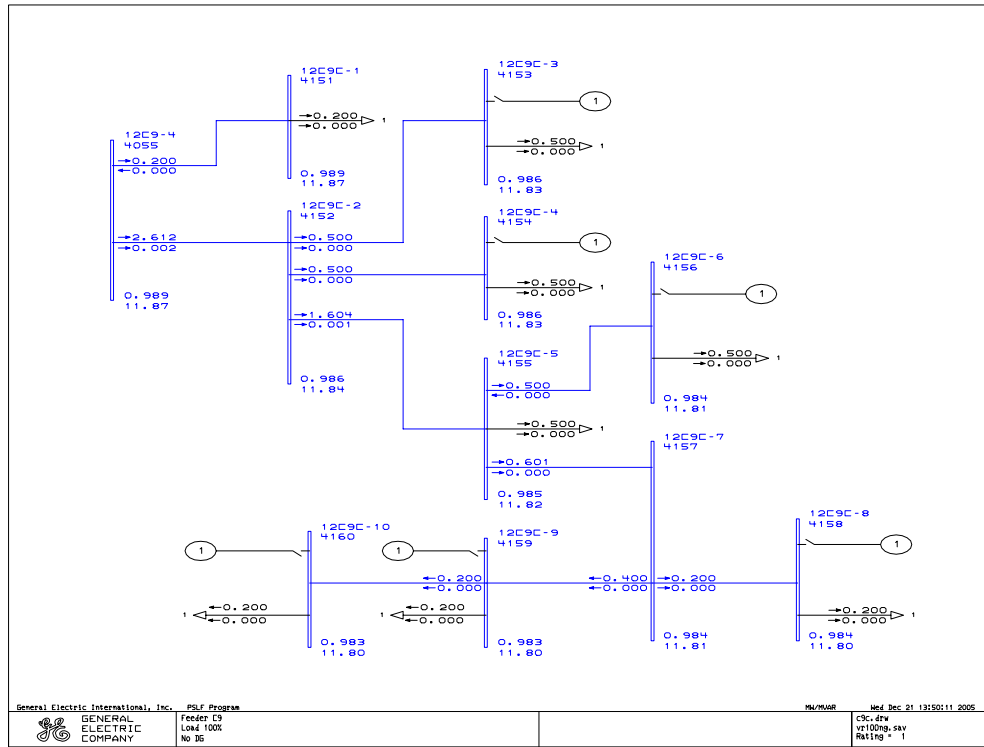
Figure 4-3: C9 Lateral Section B Configuration without Renewable DG - Peak MW and MVAR Flows



The electrical configuration for C9 lateral section C is shown in Figure 4-4. Lateral section C connects to Bus 4055, named 12C9-4 located on the main feeder, and the other busses in Section C have names including the lateral section letter as shown in the figure.

MW and MVAR flows during peak load conditions in each of the Section C branches during peak feeder load conditions and without renewable DG are shown in Figure 4-4. Busses 4153, 4154, 4156, 4158, 4159 and 4160 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

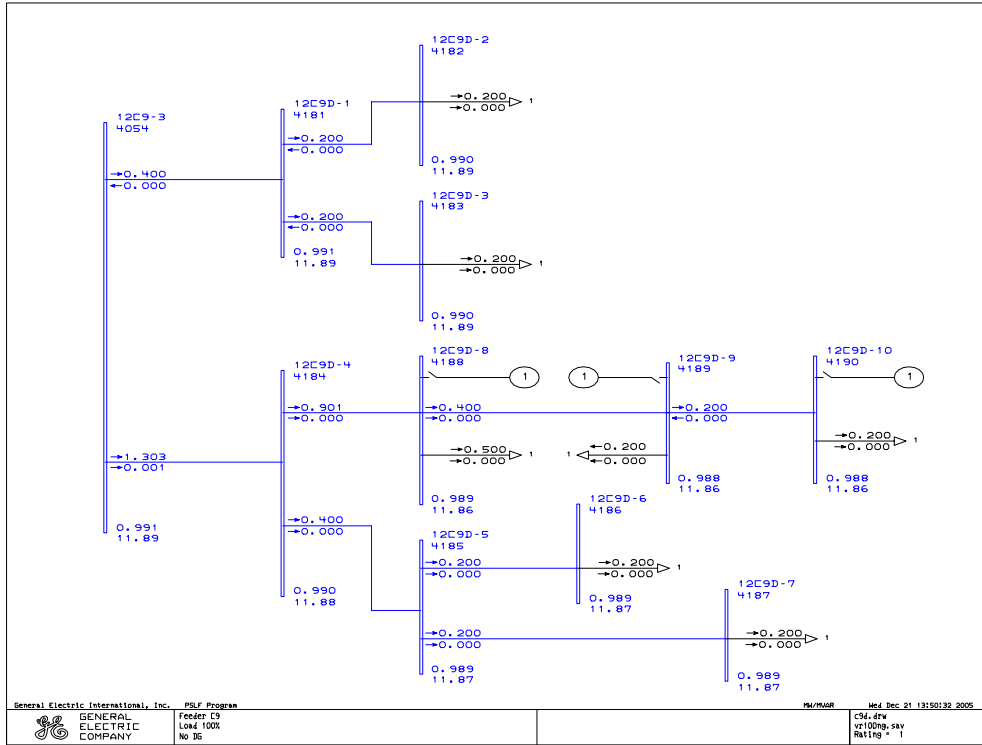
Figure 4-4: C9 Lateral Section C Configuration without Renewable DG - Peak MW and MVAR Flows



The electrical configuration for C9 lateral section D is shown in Figure 4-5. Lateral section D connects to Bus 4054, named 12C9-3 located on the main feeder, and the other busses in Section D have names including the lateral section letter as shown in the figure.

MW and MVAR flows during peak load conditions in each of the Section D branches during peak feeder load conditions and without renewable DG are shown in Figure 4-5. Busses 4188, 4189 and 4190 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

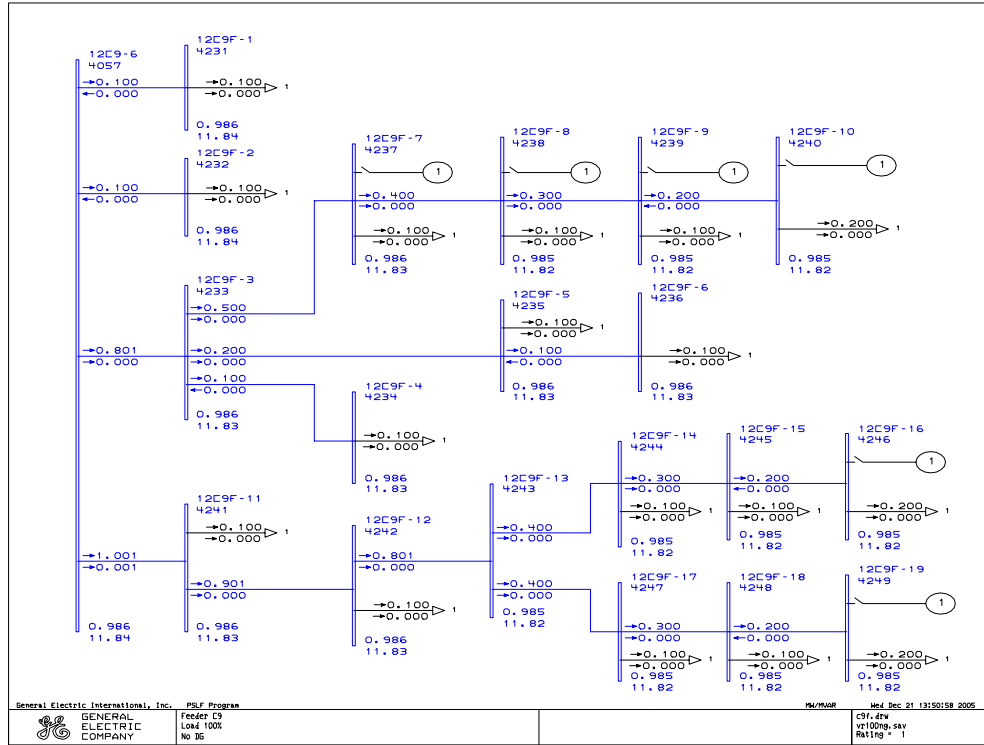
Figure 4-5: C9 Lateral Section D Configuration without Renewable DG - Peak MW and MVAR Flows



The electrical configuration for C9 lateral section F is shown in Figure 4-6. Lateral section F connects to Bus 4057, named 12C9-6 located on the main feeder, and the other busses in Section F have names including the lateral section letter as shown in the figure.

MW and MVAR flows during peak load conditions in each of the Section F branches during peak feeder load conditions and without renewable DG are shown in Figure 4-6. Busses 4237, 4238, 4239, 4240, 4246 and 4249 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

Figure 4-6: C9 Lateral Section F Configuration without Renewable DG - Peak MW and MVAR Flows



5

D6 Main Feeder and Laterals Description

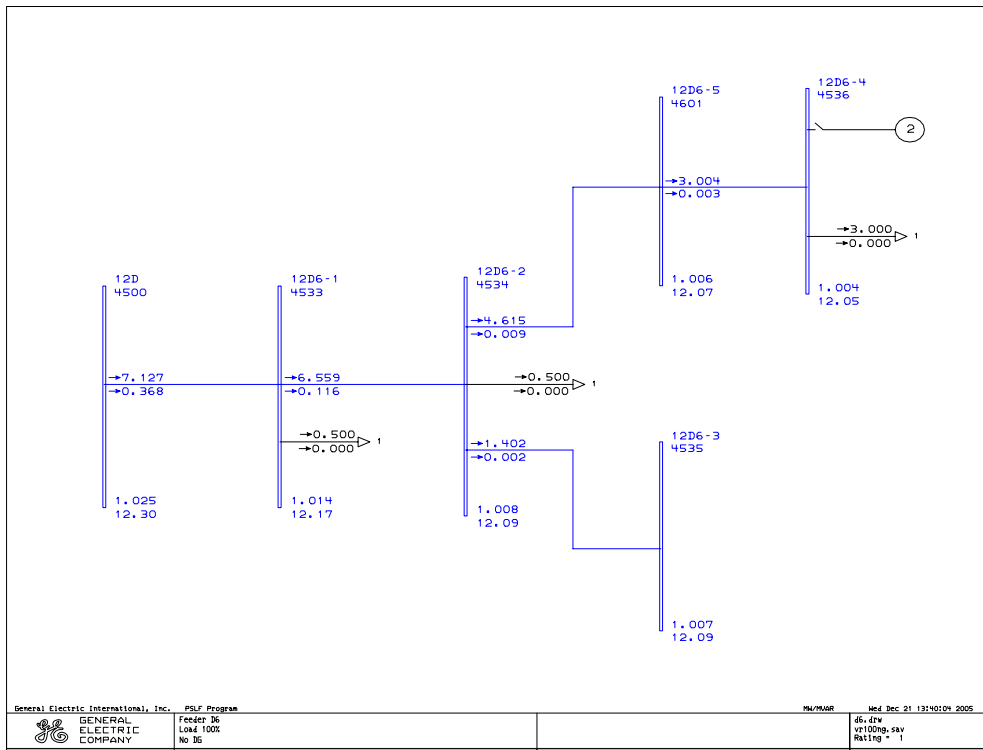
Laterals serving commercial and industrial loads were added to the main D6 12 kV feeder representation to illustrate the number of potential BI-PV locations, size and places where BI-PV will be installed on the distribution circuit, as described in later in this report. Again, this more detailed distribution circuit representation will be used for some calculations in this high-penetration interconnection study, such as feeder breaker - lateral fuse coordination, where applicable, and for the dynamic modeling in Task 3.1.10.

The D6 circuit is assumed to be relatively lightly loaded, similar to the feeder loading for 2012 in the mini-grid power flow study, serving a total peak load of 7 MW at the load busses located throughout the circuit. The D6 12 kV circuit was expanded to include the main feeder plus four lateral sections (designated A through D) serving 20 commercial and industrial load points.

The main feeder electrical configuration is shown in Figure 5-1. This is the same D6 (main) feeder configuration used for the mini-grid power flow study, as described in the Project 1.1 - Task 1.1.6, Task 1.1.9a and Task 1.1.9b final reports. Bus 4500, named 12D is located at Substation D, and the other busses have the same numbers and names described in the report. One bus, Bus 4601, named 12D6-5 was inserted in the D6 main feeder to provide a tap point for connecting feeder lateral sections A and B to the main feeder.

MW and MVAR flows during peak load conditions in each of the main feeder branches during peak feeder load conditions and without renewableDG are shown in Figure 5-1. Bus 4536 contains one potential generation location for a biogas generator, (identifier no. 2) for the high-penetration scenarios to be described later. Three load points are shown on the main feeder. Bus 4533 and Bus 4534 loads represent lumped residential loads, and Bus 4536 represents the IEUA RP-1 wastewater treatment plant served by the main feeder. The other commercial and industrial loads served by this distribution circuit have all been moved to locations in the D6 laterals described later. The electrical characteristics for the main feeder and all the lateral branches are presented in Appendix B, Table B-1.

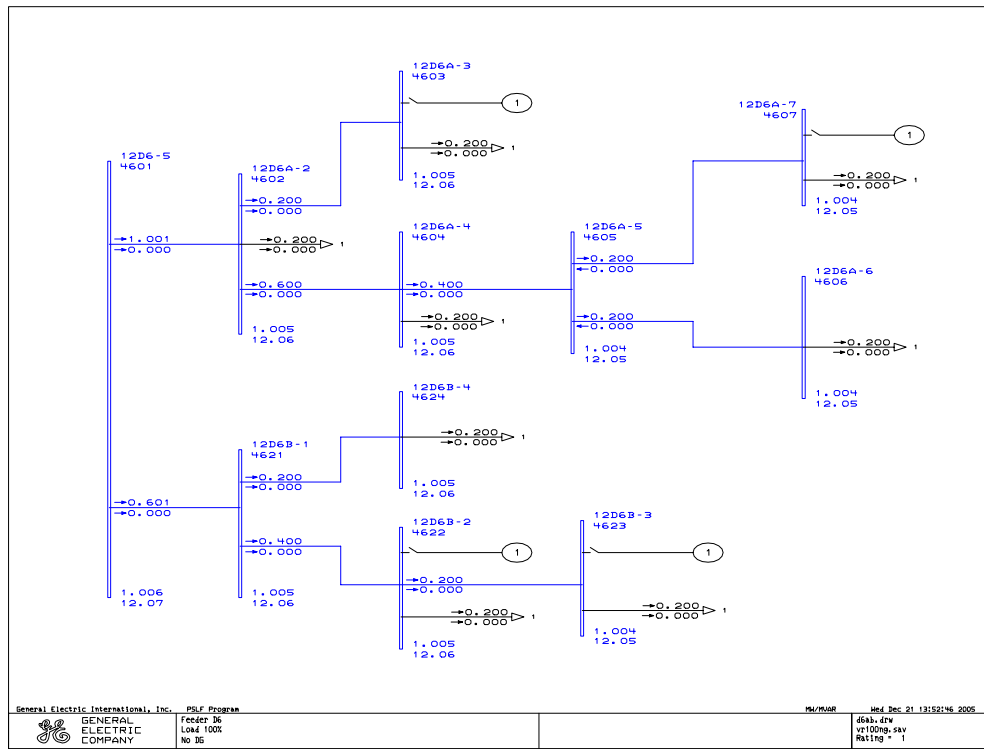
Figure 5-1: D6 Main Feeder Configuration with Peak MW and MVAR Flows



The electrical configuration for D6 lateral sections A and B are shown in Figure 5-2. Lateral sections A and B connect to Bus 4601, named 12D6-5 located on the main feeder, and the other busses in Sections A and B have names including the lateral section letter as shown in the figure.

MW and MVAR flows during peak load conditions in each of the Section A and B branches during peak feeder load conditions without renewable DG are shown in Figure 5-2. Busses 4603, 4607, 4622 and 4623 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Commercial and industrial load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

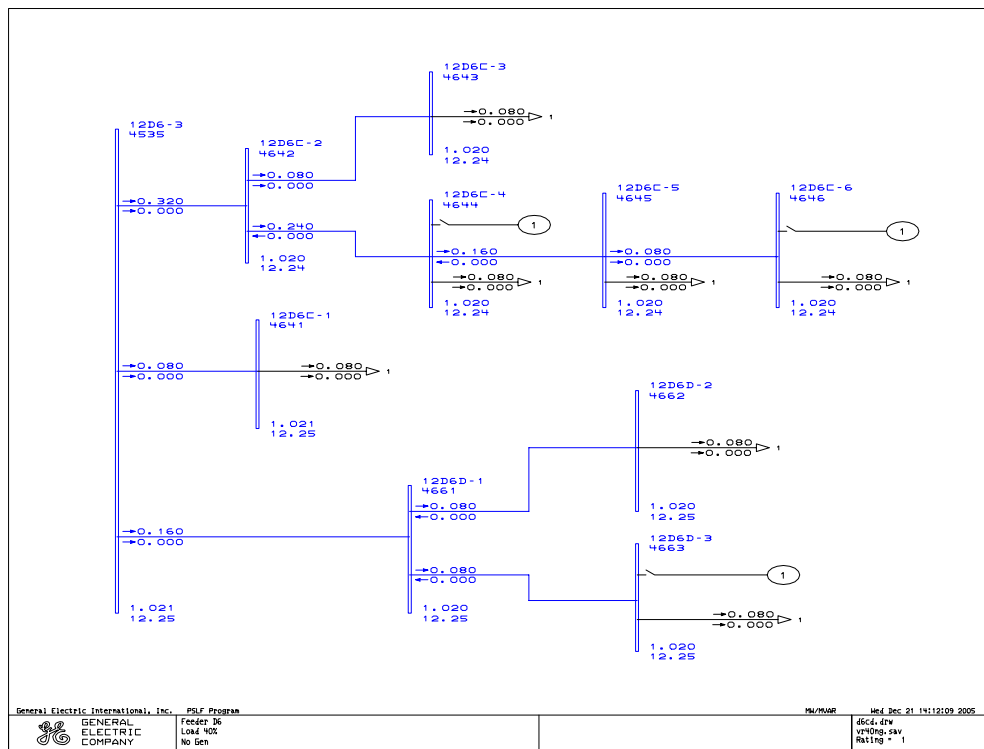
Figure 5-2: D6 Lateral Sections A and B Configuration with Peak MW and MVAR Flows



The electrical configuration for D6 lateral sections C and D are shown in Figure 5-3. Lateral sections C and D connect to Bus 44535, named 12D6-3 located on the main feeder, and the other busses in Sections C and D have names including the lateral section letter as shown in the figure.

MW and MVAR flows during peak load conditions in each of the Section C and D branches during peak feeder load conditions without renewable DG are shown in Figure 5-3. Busses 4644, 4646 and 4663 contain potential generation locations for a BI-PV generator, (identifier no. 1) for the high-penetration scenarios to be described later. Commercial and industrial load points designated by arrows, and associated peak MW and MVAR loads are also shown in the figure.

Figure 5-3: D6 Lateral Sections C and D Configuration with Peak MW and MVAR Flows



6

High-Penetration BI-PV and Biogas Renewable DG Scenarios

Three high-penetration renewable generation scenarios were developed for each of the two expanded C9 and D6 distribution primary circuits. For this study the BI-PV generation capacity installed at commercial or industrial sites is assumed to be either 225 kW_{AC} or 450 kW_{AC}. These BI-PV system sizes are compatible with the BI-PV arrays connecting to the distribution system through either one or two 225 kW Xantrex three phase inverters.

The high-penetration biogas generation capacity for this study is installed in large MW-scale generating plants consisting of one or more 1.4 MW synchronous generator units. This unit size is compatible with the two Waukesha engine generators (called *enginators* by Waukesha) currently used to generate electricity from digester gas at IEUA's RP-1 treatment facility within the mini-grid area.

Three high-penetration scenarios were developed for the Feeder C9 distribution circuit as presented in Table 6-1. Scenario A consists of a total of 6.025 MW of BI-PV distributed at various locations throughout the distribution circuit. Scenario B consists of a total of 8.875 MW with two 1.4 MW biogas generators added to the 6.025 MW of BI-PV included in Scenario A. Scenario C consists of adding more BI-PV to Scenario A, resulting in a total of 8.1 MW of BI-PV distributed at various locations throughout the feeder. The bus number and description for each renewable generation resource location is listed in the table. In addition the locations of the renewable generation resources are shown in the one-line diagrams presented in Section 4.

Table 6-1: Feeder C9 Renewable Penetration Scenarios (MW)

		Scenario A	Scenario B	Scenario C
Bus No.	Bus Name	Gen MW	Gen MW	Gen MW
4101	12C9A-1	0.225	0.225	0.225
4128	12C9B-8	0.225	0.225	0.225
4129	12C9B-9	0.225	0.225	0.225
4158	12C9C-9	0.225	0.225	0.225
4160	12C9C-10	0.225	0.225	0.225
4189	12C9D-9	0.225	0.225	0.450
4190	12C9D-10	0.225	0.225	0.450
4214	12C9E-4	0.225	0.225	0.450
4237	12C9F-7	0.225	0.225	0.450
4238	12C9F-8	0.225	0.225	0.450
4239	12C9F-9	0.225	0.225	0.450
4240	12C9F-10	0.225	0.225	0.450
4246	12C9F-16	0.225	0.225	0.450
4249	12C9F-19	0.225	0.225	0.450
4153	12C9C-3	0.450	0.450	0.450
4154	12C9C-4	0.450	0.450	0.450
4156	12C9C-6	0.450	0.450	0.450
4188	12C9D-8	0.450	0.450	0.450
4212	12C9E-2	0.450	0.450	0.450
4213	12C9E-3	0.450	0.450	0.450
4057	12C9-6		2.800	
	Total MW	6.075	8.875	8.100

Three high-penetration scenarios were developed for the expanded D6 distribution primary circuit as presented in Table 6-2. Scenario A consists of a total of 5.6 MW of biogas generation located at the IEUA RP-1 wastewater treatment plant. Scenario B consists of a total of 7.625 MW with 2.025 MW of BI-PV distributed throughout the feeder at potential commercial and industrial sites and added to the Scenario A biogas generators. Scenario C consists of adding another 1.4 MW biogas generator at the RP-1 wastewater treatment plant. Scenario A generation results in a total of 7 MW of biogas generation located on the distribution circuit. The bus number and description for each renewable generation location is listed in the table, and the locations of renewable generation are shown in the one-line diagrams presented in Section 5.

Table 6-2: Feeder D6 Renewable Penetration Scenarios

Bus No.	Bus Name	Scenario A Gen MW	Scenario B Gen MW	Scenario C Gen MW
4536	12D6-4	5.600	5.600	7.000
4607	12D6A-7		0.450	
4663	12D6D-3		0.450	
4646	12D6C-6		0.225	
4623	12D6B-3		0.225	
4603	12D6A-3		0.225	
4622	12D6B-2		0.225	
4644	12D6C-4		0.225	
	Total MW	5.600	7.625	7.000

Appendix A

Table A-1: Expanded C9 Feeder and Lateral Database

From Bus No.	From Bus Name	To Bus No.	To Bus Name	100 MVA Base R PU	100 MVA Base X PU	Rating MVA	Length Mi.
4000	12C	4052	12C9-1	0.1500	0.2500	12.0	2.0
4052	12C9-1	4053	12C9-2	0.0230	0.0380	12.0	0.3
4053	12C9-2	4054	12C9-3	0.0310	0.0390	11.0	0.3
4054	12C9-3	4055	12C9-4	0.0650	0.0440	7.3	0.3
4054	12C9-3	4056	12C9-5	0.0650	0.0440	7.3	0.3
4056	12C9-5	4057	12C9-6	0.1200	0.1700	12.0	0.3
4052	12C9-1	4101	12C9A-1	0.1107	0.0183	2.9	0.1
4052	12C9-1	4102	12C9A-2	0.1107	0.0183	2.9	0.1
4052	12C9-1	4103	12C9A-3	0.1107	0.0183	2.9	0.1
4053	12C9-2	4121	12C9B-1	0.0714	0.0179	3.7	0.1
4121	12C9B-1	4122	12C9B-2	0.0714	0.0179	3.7	0.1
4121	12C9B-1	4123	12C9B-3	0.0714	0.0179	3.7	0.1
4123	12C9B-3	4124	12C9B-4	0.0714	0.0179	3.7	0.1
4124	12C9B-4	4125	12C9B-5	0.0714	0.0179	3.7	0.1
4125	12C9B-5	4126	12C9B-6	0.1429	0.0179	3.7	0.2
4125	12C9B-5	4127	12C9B-7	0.0714	0.0179	3.7	0.1
4127	12C9B-7	4128	12C9B-8	0.0714	0.0179	3.7	0.1
4128	12C9B-8	4129	12C9B-9	0.0714	0.0179	3.7	0.1
4055	12C9-4	4151	12C9C-1	0.1107	0.0183	2.9	0.1
4055	12C9-4	4152	12C9C-2	0.1107	0.0183	2.9	0.1
4152	12C9C-2	4153	12C9C-3	0.1107	0.0183	2.9	0.1
4152	12C9C-2	4154	12C9C-4	0.1107	0.0183	2.9	0.1
4152	12C9C-2	4155	12C9C-5	0.1107	0.0183	2.9	0.1
4155	12C9C-5	4156	12C9C-6	0.1107	0.0183	2.9	0.1
4155	12C9C-5	4157	12C9C-7	0.1107	0.0183	2.9	0.1
4157	12C9C-7	4158	12C9C-8	0.1107	0.0183	2.9	0.1
4157	12C9C-7	4159	12C9C-9	0.1107	0.0183	2.9	0.1
4159	12C9C-9	4160	12C9C-10	0.1107	0.0183	2.9	0.1
4054	12C9-3	4181	12C9D-1	0.1107	0.0183	2.9	0.1
4181	12C9D-1	4182	12C9D-2	0.1107	0.0183	2.9	0.1

Table A-1: Expanded C9 Feeder and Lateral Database (continued)

From Bus No.	From Bus Name	To Bus No.	To Bus Name	100 MVA Base R PU	100 MVA Base X PU	Rating MVA	Length Mi.
4181	12C9D-1	4183	12C9D-3	0.1107	0.0183	2.9	0.1
4054	12C9-3	4184	12C9D-4	0.1107	0.0183	2.9	0.1
4184	12C9D-4	4185	12C9D-5	0.1107	0.0183	2.9	0.1
4185	12C9D-5	4186	12C9D-6	0.1107	0.0183	2.9	0.1
4185	12C9D-5	4187	12C9D-7	0.1107	0.0183	2.9	0.1
4184	12C9D-4	4188	12C9D-8	0.1107	0.0183	2.9	0.1
4188	12C9D-8	4189	12C9D-9	0.1107	0.0183	2.9	0.1
4189	12C9D-9	4190	12C9D-10	0.1107	0.0183	2.9	0.1
4056	12C9-5	4214	12C9E-4	0.1107	0.0183	2.9	0.1
4056	12C9-5	4211	12C9E-1	0.0714	0.0179	3.7	0.1
4211	12C9E-1	4212	12C9E-2	0.0714	0.0179	3.7	0.1
4211	12C9E-1	4213	12C9E-3	0.0714	0.0179	3.7	0.1
4057	12C9-6	4231	12C9F-1	0.1107	0.0183	2.9	0.1
4057	12C9-6	4232	12C9F-2	0.1107	0.0183	2.9	0.1
4057	12C9-6	4233	12C9F-3	0.0649	0.0442	7.4	0.3
4233	12C9F-3	4234	12C9F-4	0.0714	0.0179	3.7	0.1
4233	12C9F-3	4235	12C9F-5	0.0714	0.0179	3.7	0.1
4235	12C9F-5	4236	12C9F-6	0.0714	0.0179	3.7	0.1
4233	12C9F-3	4237	12C9F-7	0.0714	0.0179	3.7	0.1
4237	12C9F-7	4238	12C9F-8	0.0714	0.0179	3.7	0.1
4238	12C9F-8	4239	12C9F-9	0.0714	0.0179	3.7	0.1
4239	12C9F-9	4240	12C9F-10	0.0714	0.0179	3.7	0.1
4057	12C9-6	4241	12C9F-11	0.0649	0.0442	7.4	0.3
4241	12C9F-11	4242	12C9F-12	0.0216	0.0147	7.4	0.1
4242	12C9F-12	4243	12C9F-13	0.0216	0.0147	7.4	0.1
4243	12C9F-13	4244	12C9F-14	0.0714	0.0179	3.7	0.1
4243	12C9F-13	4247	12C9F-17	0.0714	0.0179	3.7	0.1
4244	12C9F-14	4245	12C9F-15	0.0714	0.0179	3.7	0.1
4245	12C9F-15	4246	12C9F-16	0.0714	0.0179	3.7	0.1
4247	12C9F-17	4248	12C9F-18	0.0714	0.0179	3.7	0.1
4248	12C9F-18	4249	12C9F-19	0.0714	0.0179	3.7	0.1

Appendix B

Table B-1: Expanded D6 Feeder and Lateral Database

From Bus No.	From Bus Name	To Bus No.	To Bus Name	100 MVA Base R PU	100 MVA Base X PU	Rating MVA	Length Mi.
4500	12D	4533	12D6-1	0.1400	0.5200	12.0	1.4
4533	12D6-1	4534	12D6-2	0.1000	0.2500	12.0	0.5
4534	12D6-2	4535	12D6-3	0.0420	0.0990	12.0	0.2
4534	12D6-2	4601	12D6-5	0.0433	0.0295	7.3	0.2
4601	12D6-5	4536	12D6-4	0.0433	0.0295	7.3	0.2
4601	12D6-5	4602	12D6A-2	0.0714	0.0179	3.7	0.1
4602	12D6A-2	4603	12D6A-3	0.0714	0.0179	3.7	0.1
4602	12D6A-2	4604	12D6A-4	0.0714	0.0179	3.7	0.1
4604	12D6A-4	4605	12D6A-5	0.0714	0.0179	3.7	0.1
4605	12D6A-5	4606	12D6A-6	0.0714	0.0179	3.7	0.1
4605	12D6A-5	4607	12D6A-7	0.0714	0.0179	3.7	0.1
4601	12D6-5	4621	12D6B-1	0.1430	0.0358	3.7	0.2
4621	12D6B-1	4624	12D6B-4	0.0714	0.0179	3.7	0.1
4621	12D6B-1	4622	12D6B-2	0.0714	0.0179	3.7	0.1
4622	12D6B-2	4623	12D6B-3	0.0714	0.0179	3.7	0.1
4535	12D6-3	4641	12D6C-1	0.1107	0.0183	2.9	0.1
4535	12D6-3	4642	12D6C-2	0.1107	0.0183	2.9	0.1
4642	12D6C-2	4643	12D6C-3	0.1107	0.0183	2.9	0.1
4642	12D6C-2	4644	12D6C-4	0.1107	0.0183	2.9	0.1
4644	12D6C-4	4645	12D6C-5	0.1107	0.0183	2.9	0.1
4645	12D6C-5	4646	12D6C-6	0.1107	0.0183	2.9	0.1
4535	12D6-3	4661	12D6D-1	0.0714	0.0179	3.7	0.1
4661	12D6D-1	4662	12D6D-2	0.0714	0.0179	3.7	0.1
4661	12D6D-1	4663	12D6D-3	0.0714	0.0179	3.7	0.1