DNV·GL

SAINT LUCIA INTERCONNECTION REQUIREMENTS STUDIES

Steady State Analysis and Impacts of 2 MW and 1 MW Solar PV Plants on the Pierrot and View-Fort Feeders

For: Saint Lucia Electricity Services Limited
Through: The Carbon War Room

Project No.: 84430449
Rev: A, Status: DRAFT
Date: 8 December 2014

Project name:	St. Lucia Interconnection Requirements Studies	DNV GL Energy
Report title:	Steady State Analysis and Impacts of 2 MW and 1 MW Solar PV Plants on the Pierrot and View-Fort Feeders	Power Systems Planning 2420 Camino Ramon, Suite 300 San Ramon CA 94583
Customer:	LUCELEC through Carbon War Room	
Contact person:	Victor Emmanuel	
Date of issue:	8 December 2014	Tel: (925) 327-3030

Project No.: 84430449
Revision: A - Draft

Prepared by:	Verified by:	Approved by:
Mahtis Moayedi Senior Engineer	Ronald Davis Principal Consultant	Chad Nancarrow Senior Engineer, Project Manager

☐ Unrestricted distribution (internal and external)
☐ Unrestricted distribution within DNV GL
☐ Limited distribution within DNV GL after 3 years
☒ No distribution (confidential)
☐ Secret

Keywords:
Renewable Energy, Interconnection, St. Lucia,

Reference to part of this report which may lead to misinterpretation is not permissible.

Rev. No.	Date	Reason for Issue	Prepared by	Verified by	Approved by
A	12/8/2014	Draft for review by LUCELEC			

Table of contents

1 INTRODUCTION

DNV GL has been contracted by the Carbon War Room (CWR) under the Ten Island Challenge program to perform an interconnection analysis on the Pierrot and Vieux-Fort distribution feeders owned and operated by St. Lucia Electricity Services Limited (LUCELEC) on the island of St. Lucia. The objective of the analysis is to identify the technical limitations to installation of approximately 3 megawatts (MW) of photovoltaic (PV) generators on the two feeders at the Vieux-Fort substation, including 2 MW PV on the Pierrot feeder and 1 MW PV on the Vieux-Fort feeder. Following the completion of this stage of the analysis, the system will be further analysed for higher penetrations of solar generations and the PV capacity at which technical limitations will be identified. The present analysis includes only steady-state analysis, and does not include transient results. The analysis is carried out using SynerGEE Electric, and the post-processing is done using the automated Cluster Results Tool developed by DNV GL.

The diagram below depicts the electrical network of St. Lucia and the feeders Pierrot and Vieux-Fort at the Vieux-Fort substation that are the focus of this study for the integration of the 3 MW of solar PV generation.

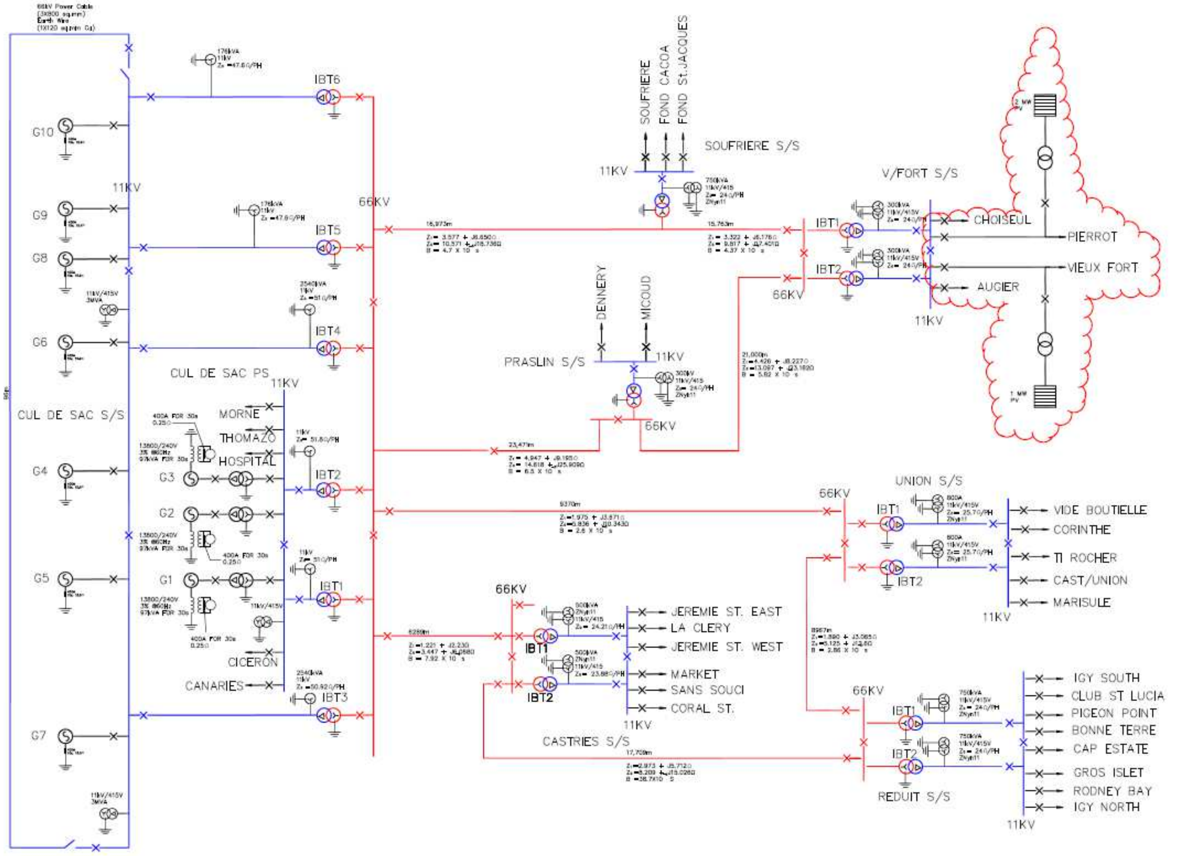

Figure 1.1: St. Lucia Electrical Network

The objective of this study is to identify existing and potential steady state issues of the utility's network before and after the addition of the 3 MW solar generation. In order to carry out the study, analyses are required of the extreme cases: the minimum daytime peak load on the system and the maximum daytime peak load on the system. As the impact of PV is of interest, only the daytime load profiles – at times when the PV systems could be operating at full output – are investigated.

The results from the analysis are processed to identify (for each feeder) where certain technical criteria are exceeded and what limitations this will imply for the future integration of 3 MW of solar PV generation.

The following sections describe the technical criteria, the analysis process, data inputs, the assumptions associated with the different data modifications, the results from the analysis, and the conclusions that may be drawn from this analysis.

2 TECHNICAL CRITERIA

Table 2.1 below describes the technical criteria and the defined limits that are covered in this study:

Parameter	Limit	Effects and Impacts
Backfeed	Reverse power flow at feeder head or at any line segment along the feeder	Transformers and protective equipment can respond incorrectly if not set up to recognize and adapt to changes in direction of power flow.
Loading	Line loaded over 100% of specified capacity	Equipment would require to be upgraded.
Voltage	Voltage at any point on the distribution system is less than 95% or greater than 105% of nominal.	Customers would experience high or low voltage problems and service may be lost if voltage remains outside nominal ±5%.

Table 2.1: Technical Criteria

3 ANALYSIS PROCESS

3.1 General

The method of analysis is designed in order to assess the system with respect to all criteria identified above, for a number of different PV penetrations. In order to achieve this, a number of different cases are run, which are made up of different combinations of load profile and installed PV capacity. The different options for each of these parameters are illustrated in Figure 3.1 below:

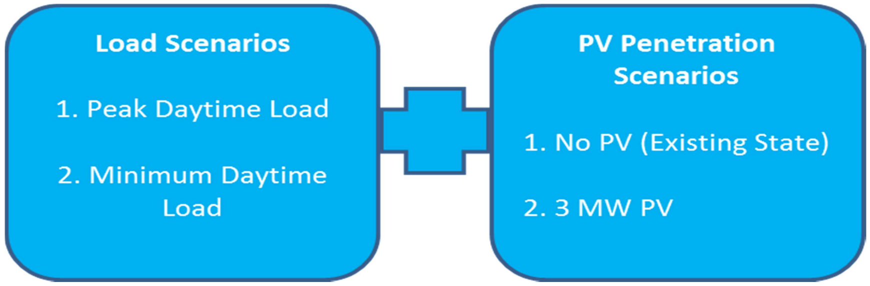

Figure 3.1: Scenario Combinations

By forming all possible combinations of the above options, the following four (4) cases are defined:

Case Name	Load Profile	Installed PV Penetration (% of Peak Load)
Case 1	Peak	0%
Case 2	Min	0%
Case 3	Peak	3 MW
Case 4	Min	3 MW

Table 3.1 Scenario Definitions

For each of these cases, eight (8) steady-state load flow analyses are performed to represent a four-hour segment of the day – 10am to 2pm – split into 30-minute intervals. For each of these time-steps, only the load value will change, the installed solar generation is fixed, and the output is maintained at 100% in order to simulate the maximum impact of the installed PV on the system. These analyses are performed both with the future PV installed at locations marked on Figure 6.2. and without PV.

The use of these cases to assess the different criteria is discussed in the sections below.

3.2 Steady-State Voltage

For each load flow performed, the maximum and minimum voltage on each feeder is calculated. If these values are within the range 0.95 per unit to 1.05 per unit, then there is no violation. If either the maximum or minimum voltage is outside this range, there is a violation. If the violation occurs in either Case 1 or Case 2 in the table above (when there is no PV installed), then the model is checked to identify any inaccuracies, as it is generally assumed that there should not be any voltage violations in an existing condition. If voltage violations occur outside of the first two cases, the location of the violation is identified and presented.

3.3 Thermal Loading

For each load flow analysis performed, the maximum continuous loading on each feeder is calculated using SynerGEE. Again, the first two cases are checked first to ensure that the customer load alone is not causing load violations. After these are verified, the maximum continuous loading on the feeders for all the other cases is calculated. If the continuous loading is above 100% on any section, this constitutes a violation. As with the voltage results, if a violation is found then the location and reason for the violation (if it is identifiable) is identified and presented.

3.4 Backfeed

The backfeed study is performed by identifying the minimum daytime load on the feeder. As it is assumed that the PV output could be at 100% at any time between 10am and 2pm, this minimum load represents the PV penetration at which reverse power flow may occur. Backfeed may also occur during the maximum daytime load, if the PV output is higher than the peak load amount.

4 INPUT DATA REQUIREMENTS

4.1 Feeder Model

The Feeder Model is the geographical layout of the system, the equipment specifications and the connected load on the circuits. The model for the two circuits was built using the feeder map drawing provided by LUCELEC that consisted of the two feeders geographic layouts, feeder size and lengths, switching device locations, and distribution transformer size and location.

Sub-station connections and equipment are checked for connectivity and correct settings;

Peak load analysis is performed using the feeder data provided by LUCELEC from April 1st to October 31st 2014, with no PV generators on to identify any line loading violations. Any violations in this condition will be reported to LUCELEC for confirmation, and if necessary, the conductor specification will be corrected.

4.2 Minimum and Peak Daytime Load Profiles

For the extreme cases in the analysis, it is required that the minimum daytime, and maximum peak daytime load profiles to be identified for the feeders. In this case, 'daytime' refers to the period between 10am and 2pm where the PV output could be at 100%. The maximum daytime peak and minimum daytime load values are obtained from the feeder load data provided by LUCELEC. This data set includes 15- minute load information from April 2014 to October 2014.

Feeder	Daytime Peak Load (kW)	Daytime Minimum Load (kW)
Pierrot	4770	1998
Vieux-Fort	4888	1353

Table 4.1: Daytime Peak and Minimum Load per Feeder

4.3 Validation Data

Data is required to verify that the results obtained from the analysis in the model are consistent with those that occur in real life. The parameters which can be checked are the voltage and the transformer LTC position. Data required to check these results are one-day SCADA data profile which includes demand (kW, kVAR and kVA), voltage measured at the transformer and LTC position, or BMI data which does not include LTC position.

This data has not been provided by LUCELEC, and therefore voltage levels in the circuits analysed could not be validated.

4.4 Use of Data and Available Results

The input data described in the sections above allows various analyses to be performed. The table below shows which data is required for each of the technical criteria identified in the table in section 2.

Criterion	Data Required
Backfeed	Load Data
Line Loading	Load Data, Feeder Model
Voltage	Load Data, Feeder Model, Validation Data

Table 4.2: Data Required for Technical Criteria

5 ASSUMPTIONS

5.1 Switching Configuration

Status of the switches modelled in SynerGEE for the steady state analysis are taken from the information provided in the St. Lucia feeder map with one exception - all switches are modelled in a closed status apart from the switches listed below:

Switch Status on the Feeder Map (NO/NC)	Switch Status Modelled
Ring Main LBS\Pierrot\NO	Open
Brewery LBS\Pierrot\NO	Closed
Fort Highway LBS\Pierrot\NO	Open
Vieux-Fort Round about LBS\Vieux-Fort\NO	Open

Table 5.1: Switch Status

The switch at the Brewery LBS\Pierrot is modeled in a closed position to maintain connection on the section it is connected to.

6 CLUSTER DESCRIPTION

The figures below show the geographic location of the two feeders analysed with interconnection to the 3 MW PV sites. Pierrot and Vieux-Fort feeders that are fed from the Vieux-Fort substation are proposed to be interconnected to the two solar sites of 1 MW in the west and 2 MW in the east.

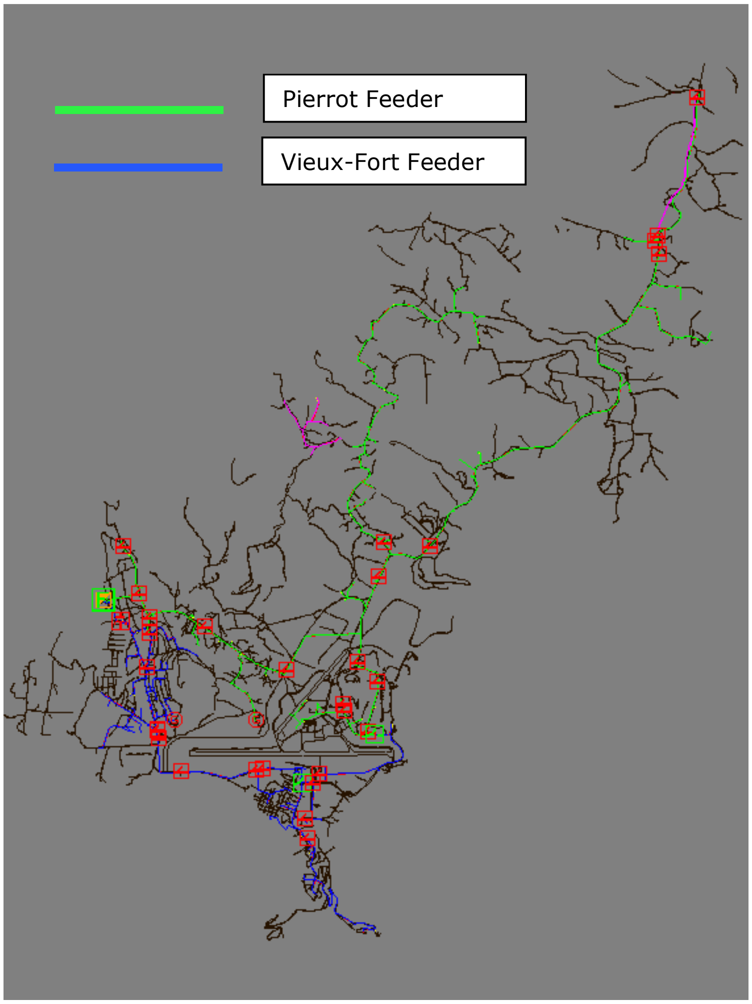

Figure 6.1: St. Lucia (Pierrot and Vieux-Fort) Feeder Map

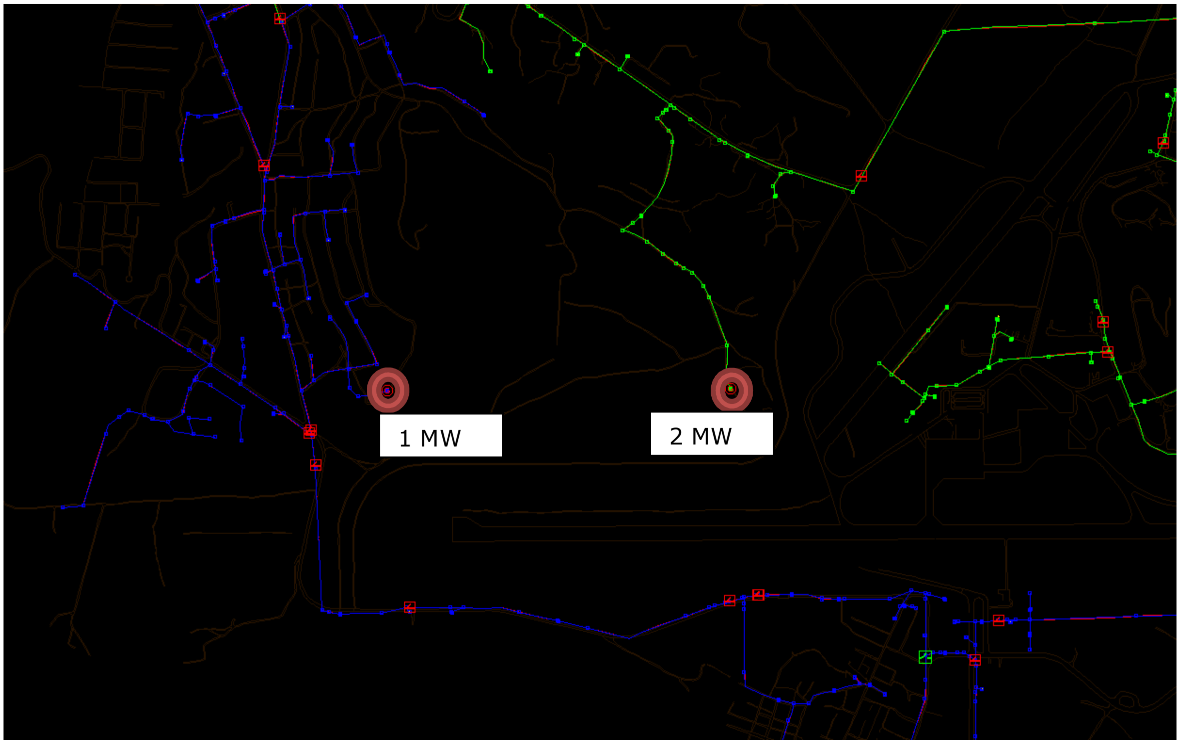

Figure 6.2: St. Lucia (Pierrot and Vieux-Fort) PV Locations (3 MW)

Table 6.1 below presents the feeders included in the analysis, the historical peak load value, and the existing and queued PV generation on the circuit:

Feeder	Maximum Daytime Peak (kW)	Existing PV (kW)	Future PV (kW)	Future PV (% of Maximum Daytime Peak)
Pierrot Feeder	4777	0	2000	42
Vieux-Fort Feeder	4888	0	1000	20

Table 6.1: St. Lucia Feeder Data

6.1 Vieux-Fort and Pierrot Feeders Load Profiles

Figure 6.3 below shows the minimum load day profiles for the feeders included in the system.

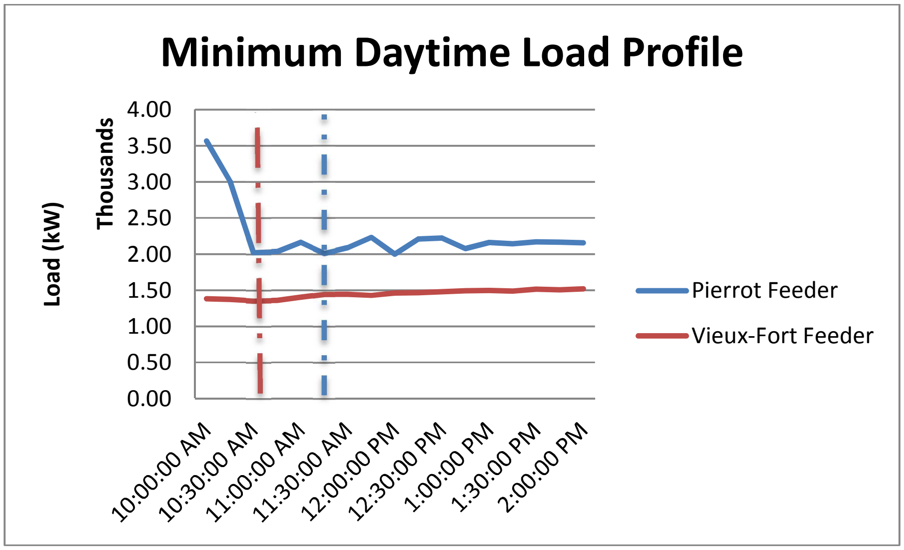

Figure 6.3: Pierrot and Vieux-Fort Feeders Minimum Load Profiles

The figure below shows the peak load day profiles for the feeders included in the system in kW:

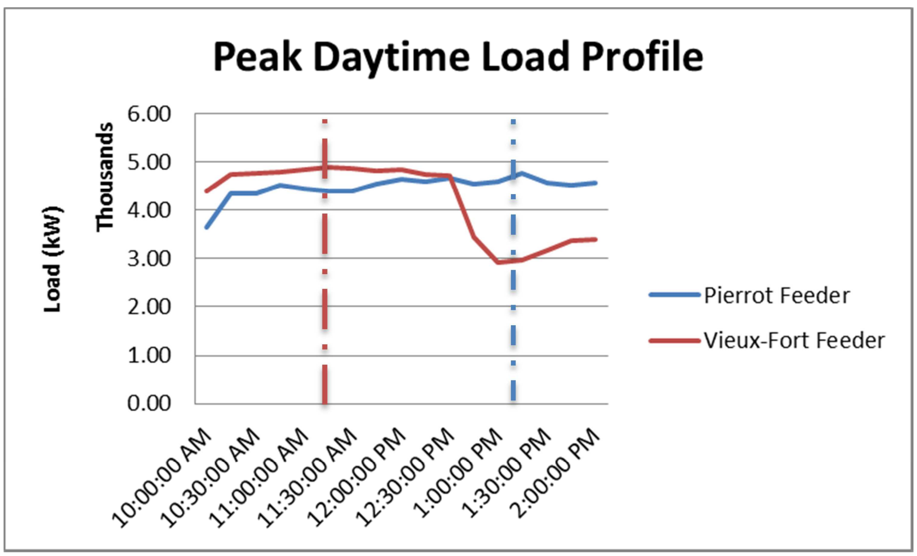

Figure 6.4: Pierrot and Vieux-Fort Feeders Peak Load Profiles

7 RESULTS

Table 7.1 shows the results for the feeders in the cluster.

Feeder	Maximum Daytime Peak (kW)	Existing PV %	Planned Future PV %	Voltage Violation	Loading Violation	Backfeed Violation
Pierrot Feeder	4770	0%	42%	None	None	None
Vieux-Fort Feeder	4888	0%	20%	None	None	None

Table 7.1: Pierrot and Vieux-Fort Feeder Results

As indicated in the above table, there are no violations in any of the steady state criteria monitored for the feeders. Both feeders operate within the steady state criteria for voltage operation and line loading in all scenarios.

No instances of backfeed were identified with the addition of PV generation to either of the feeders at any loading scenario.

Figures 7.1 and 7.2 show the maximum and minimum voltage levels for both feeders during the two iterations of solar generation over the time span investigated in this study. The maximum and minimum voltages in all cases remain within the voltage thresholds of +/- 5% deviation from 100% of the rating:

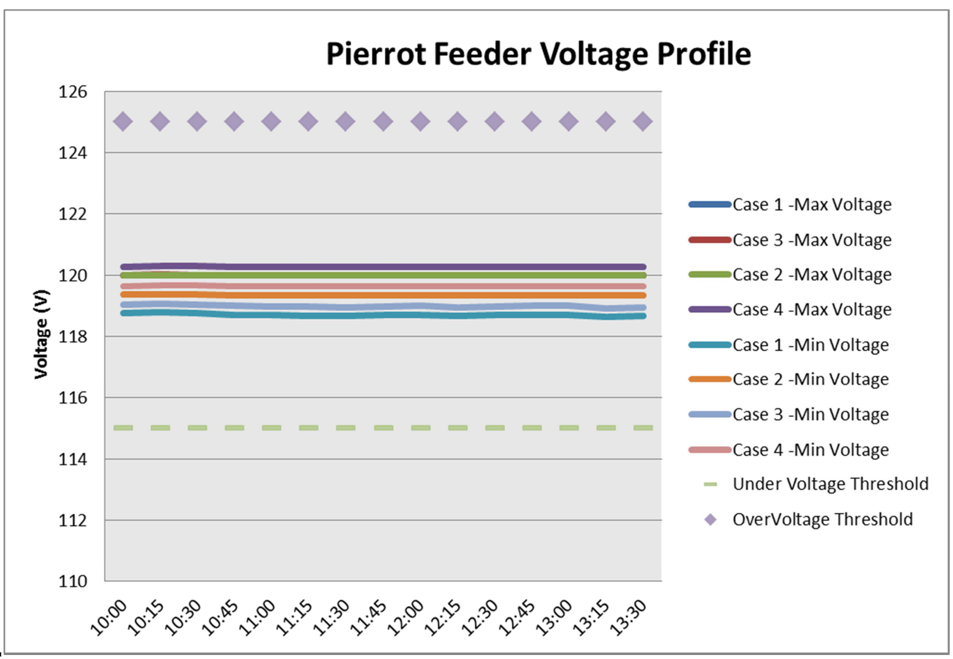

Figure 7.1: Pierrot Feeder Voltage Profile

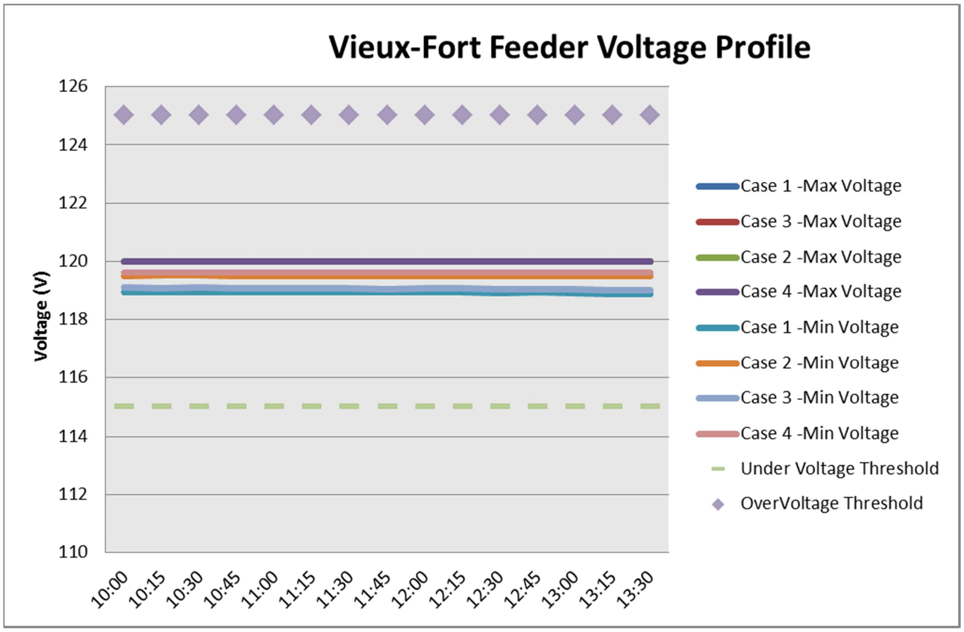

Figure 7.2: Vieux-Fort Feeder Voltage Profile

Figure 7.3 below demonstrates the load flow along the Pierrot feeder during the minimum daytime loading and the effect of solar generation on the load flow as a function of feeder length. The first 0.3 miles of the feeder demonstrate negative power flow due to low concentration of load in comparison to the high amount of PV generation.

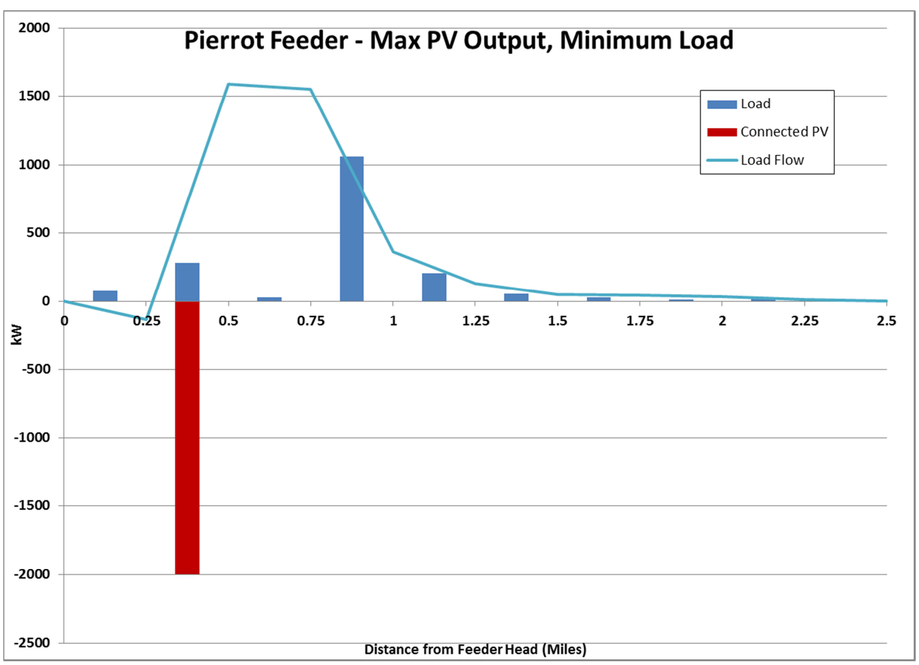

Figure 7.3: Pierrot Feeder Minimum Load Profile and 2 MW PV Load Flow

Figure 7.4 shows the load flow along the Vieux-Fort feeder during minimum daytime load and the effects of the 1 MW PV generation if installed at the shown distance from the feeder head.

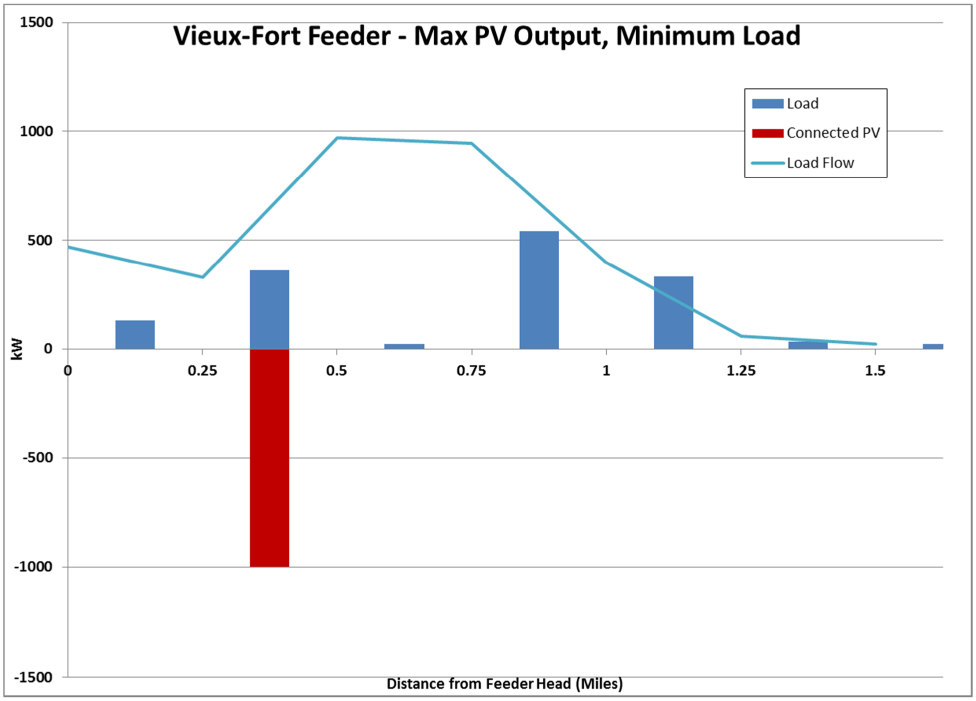

Figure 7.4: Vieux-Fort Feeder Minimum Load Profile and 1 MW PV Load Flow

8 CONCLUSIONS

The analyses presented in this report are intended to identify the technical limitations to the deployment of 2 MW PV on the Pierrot feeder and 1 MW PV on the Vieux-Fort feeder. The feeders' locations, loading and existing PV generation are presented, along with the maximum daytime peak and minimum daytime load profiles. The analysis is split into 4 cases representing the existing PV generation status of the network at 0% and the planned PV capacity of 3 MW total for the feeders for daytime peak and minimum loading conditions, in order to identify the potential steady state violations of the PV deployment.

The results show that voltage and loading limits were not violated on either feeder with the addition of the 3 MW PV generation. There are no instances of back feed on the feeders at any loading scenario. The Pierrot feeder demonstrates minimal negative load flow at sections closer to the feeder head that happen to be in the close vicinity of the 2 MW PV site. The negative load flow is due to the low concentration of load in comparison to the large amount of generation and is not an issue for the feeder and the transformer substation.

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter and greener.