1. Bartica Power Sector

1.1 Overview

Bartica Power Sector is operated by the Guyana Power and Light Inc (GPL), which is a vertically integrated power company that generates, transmits, distributes and sells electric energy to customers.

The Guyana Power and Light Inc. is now integrated into the development plans of the “Ministry of Infrastructure” which now controls the power sector and defines its regulatory framework.

1.2 Grid Expansion

Distribution grid system expansion for Bartica can be conceptualized in three forms:

1. Increase in demand in all sectors as a result of township in April 2016
2. Unserved areas - 4 & 5 miles housing scheme (approx. 400 and 320 customers, receptively)
3. Additional energy sources (Hydro, Solar, Biogas)

Similarly to most emerging countries where there are renewable energy sources or a reliable supply of energy is made available, Bartica expects a considerable load growth in the coming years. In 2036 the peak load is expected to be around three times higher than in 2015.

1.3 Voltage Levels and Grid Layout

1.3.1 Main Existing Distribution Grid

Bartica distribution grid as shown in figure 1 consists of three (3) voltage levels. These are:

1. 480V - Generation
2. 4.16kV - Generation and Secondary Medium Voltage Distribution
3. 13.8kV – Primary Medium Distribution Lines

The Bartica power sector is divided into two main categories. These are:

1. Generation
2. Distribution

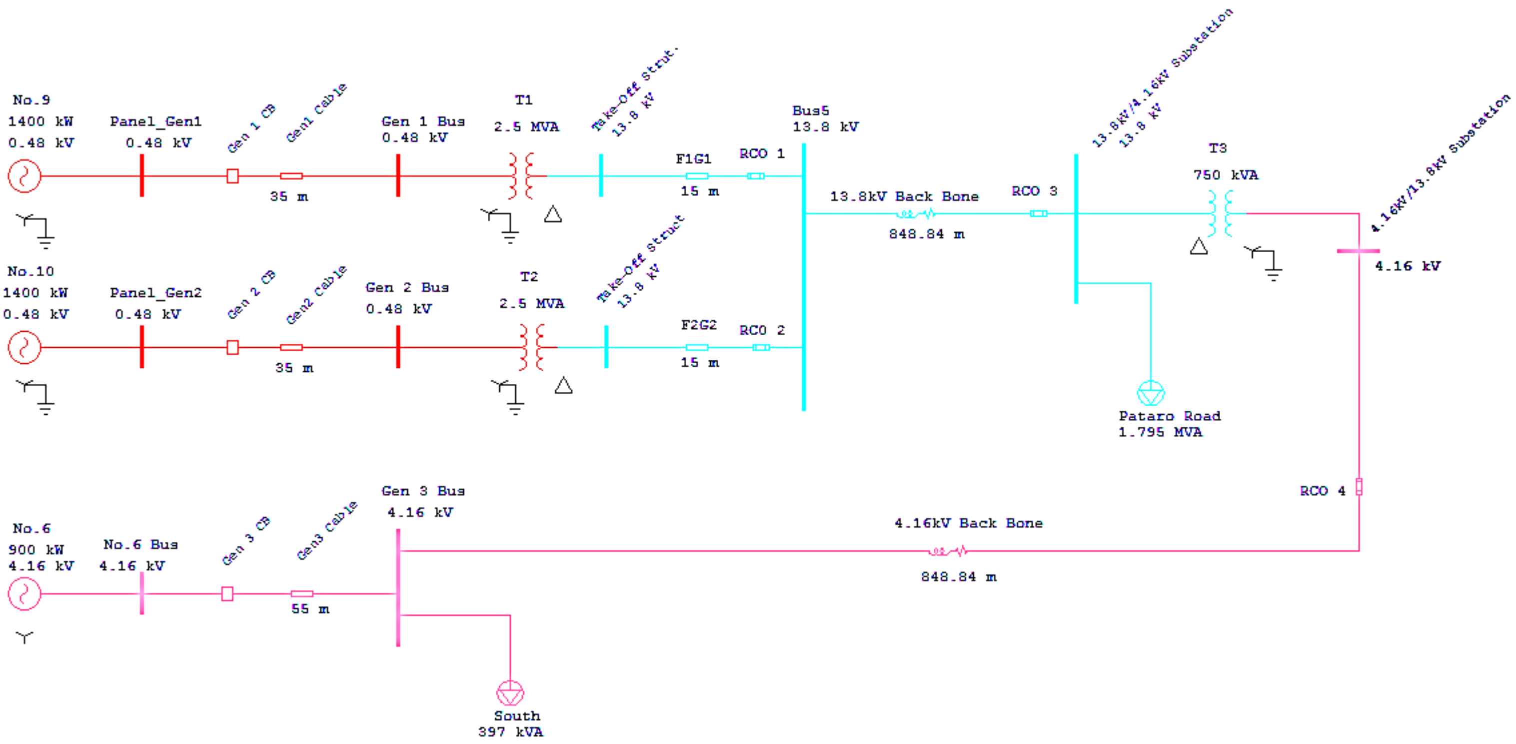

Figure 1: Single Line Diagram of Bartica

1.3.2 Generation

Presently, Bartica Power Plant consists of three (3) diesel power generators. The name plates for these generators are as follow:

Table1. Basic Name Plate Data for Diesel Generators at Bartica

Item No.	Name of Generator	Voltage (V)	Nominal Peak Output Capability (MW)	Frequency (Hz)
1	No.9	480	1.4	60
2	No.10	480	1.4	60
3	No.6	4160	0.9	60

During a site visit the following observations were made on the diesel generating sets:

1. All of the units had already accumulated over 22,000 hrs and first major overhauls.
2. Oil and water leaks were visible on operational units.
3. Peak load at location is approximately 1.96 MW
4. Though these units are operational, they have all undergone their first PM cycle of top and major overhauls. From the data provided these units are fast approaching their next PM schedule.
5. The cost per kWh produced will be significantly increased for future operations.

6. These are the older type of Mechanical Units.

The engine status for each generating set is summarized in table 2.

Table 2: Bartica Generator Engine Status

Unit	Present R/H	Last O/haul R/hours	R/H Since Last O/H	Last Type Overhaul	Next O/haul Hours	Next type O/haul
#9	60,441.49	53655.2	6786.29	MAJOR	56862.19	MAJOR
#10	10,410.58	5,006.00	5,404.58	MAJOR	14,048.00	TOP
#6	52712.91	49362.19	3650.72	TOP	7500	TOP

The general performance of the generating sets can be summarized as shown in table 3.

Table 3: Generator Performance Status ending the month of July, 2015

UNITS	# 6 UNIT	# 9 UNIT	#10 UNIT	TOTAL
Gross Gen. (MWH)	252.894	503.531	260.273	1016.698
Operating Cap. (MW)	0.9	1.4	1.4	3.7
Availability (%)	85.75%	96.66%	94.04%	-
Plant Load Factor (%)	35.86	59.06	44.85	68.26
Thermal Efficiency (%)	32.13	41.48	32.5	36.28
Fuel Rate (Gals/MWH)	69.39	53.75	68.6	61.44
Lube Oil Rate (Gals/MWH)	0.06	0.07	0.04	-

1.3.3 Substation Transformers

The Bartica power grid consists of three (3) substation transformers as shown in table 4. These are generally used to step up the generated voltage to primary distribution level at 13.8kV. However, T3 has a different function since power flow can be bilateral. This substation is basically used to integrate electricity at 13.8kV and 4.16kV.

Table 4: Substation Transformers Ratings and Locations

Name	Ratings (kVA)	Primary Voltage	Secondary Voltage	Location
T1	2500	480	13.8	Bartica Power Plant
T2	2500	480	13.8	Bartica Power Plant
T3	750	4160	13.8	5th street and 7th avenue

1.3.4 Distribution Grid

As previously mentioned regarding voltage levels, 13.8kV is considered to be the main voltage level for power distribution. The other level, 4.16kV was previously mentioned as a distribution voltage, however, this voltage level is presently in the process of being phased out.

Presently in Bartica, there is only one feeder which continues to operate at 4.16kV, the South Feeder. It is proposed that by the end of this year (2015) all distribution feeders would be upgraded to 13.8kV as shown in figure 2.

Bartica presently has two (2) main feeders. These are:

1. Pataro Road - 13.8kV
2. South - 4.16kV

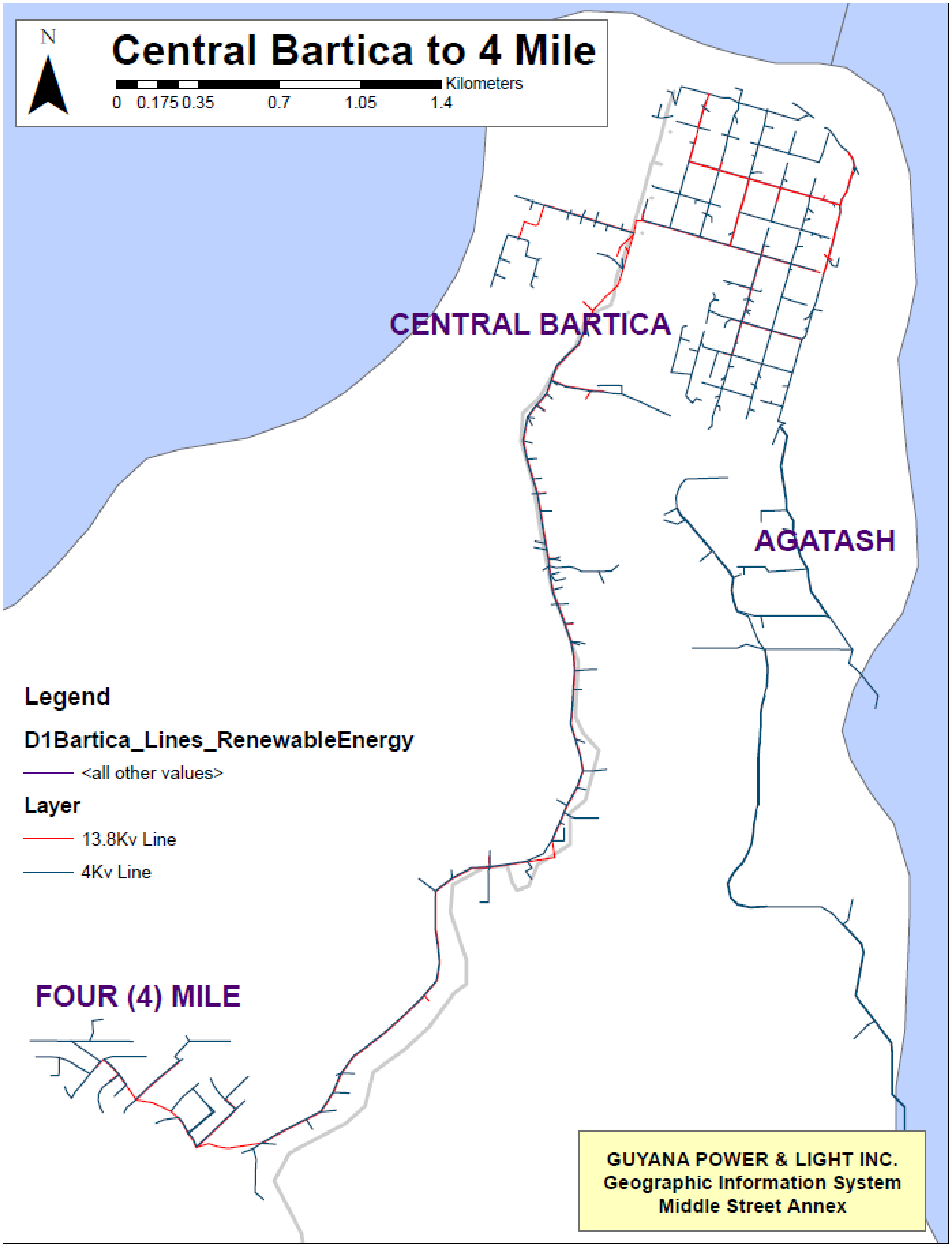

Figure 2: Bartica Distribution Grid

1.3.4.1 Pataro Road Feeder

The Pataro road feeder begins at 5th street and 7th avenue and ends at the 4 mile junction. The "back-bone" of this feeder is approximately 5.16km in the length with a combination of oxlip and tulip conductors which makes up the main branch and seven (7) spurs (secondary branches). One of spurs feeds into the West Indian Housing Scheme and another into the 4 mile Housing Scheme. In addition, this feeder supplies electricity to the northern section of Bartica (Central Bartica).

The total peak load of the Pataro road feeder which includes the Northern section of Bartica is 1.4MW at an approximate power factor of 78%. Single phase loads on this feeder accounts for 95 % of the total load while the remaining 5% are three phase. The three phase loads include schools, water-well and guest house.

Observations have revealed that majority of the single phase loads are connected across the **A** and **C** phases of the primary distribution lines. This leads to load imbalance which results in primary voltage imbalance and unnecessary lines losses.

1.3.4.1 South Feeder

The South feeder begins at the power plant and heads into the Mongreppo-Byderabo-Agatash Housing Schemes. The "back-bone" of this feeder is approximately 1.988km in length with a combination of copper and ant conductors and four (4) spurs (secondary branches). Two of the four are considered as main spurs which supplies electricity to the Byderabo and Agatash Housing Schemes.

The total peak load of the South feeder which includes all spurs and loads on the "back-bone" is 298 kW at an approximate power factor of 75%. There is a predominant amount of single phase loads which accounts for 97% while the remaining 3% are three phase. The three phase loads include commercial business, market and sawmill. The sawmill is presently out of operation. This accounts for the comparatively low loading of this feeder.

Similar observations as it relates to load imbalance was observed on this feeder.

1.4 Present Grid Operation

Electricity is generated at 480V and 4.16 kV and is integrated into the 13.8kV primary distribution grid as previously described. Along the length of the primary and secondary distribution feeders, electricity is made available to customers by means of stepdown pole mounted transformers as per demand of a cluster of customers.

The peak demand at the power plant was recorded to be 1.961 MW on the June 23, 2015 at 7pm. This case was simulated and yields the following results as shown in table 5.

Table 5: Generation Dispatch

Feeder	P (kW)	Q(kVAr)	Generation (kW)		Load Dispatch	
			P (kW)	Q(kVAr)	P (%)	Q (%)
Pataro Road	1479	1187	1960	1650	75.42	71.94
South	464	409			23.66	24.79
Distribution Line Losses	18	54.73			0.92	3.32
Total	**1961**	**1650**				

Voltage at all nodes are within acceptable range as specified by ANSI C84.1, this is as a result of adjustments of the substation transformer tap positions. However, the generated reactive power is extremely high as a result of the low power factor.

Since the 4.16kV feeds into the 13.8kV grid as well as directly to loads, it must be pointed out that approximately 40% of the power generated at 4.16 kV is transmitted to the substation T3. The remaining 60% is distributed along the South Feeder and its spurs.

Further details of the grid performance are highlighted in the following tables.

Table 6: Main Branch and Substation Transformer Performance

ID	kW Flow	kvar Flow	Amp Flow	% Loading	kW Losses	kvar Losses
4.16kV Back Bone	79.017	-116	19.43	23	1.559	0.444
13.8kV Back Bone	1405	1309	80.14	24	3.395	5.906
T1	741	671	1207	39.3	3.905	23.429
T2	672	684	1156	37.6	3.615	21.689
T3	77.377	-116	5.856	18.6	0.082	0.49

Table 7: Generator Performance

ID	Rating	Rated kV	MW	Mvar	Amp	% PF	% Generation
No.6	0.9 MW	4.16	0.543	0.293	85.62	88.03	60.3
No.9	1.4 MW	0.48	0.744	0.672	1207	74.21	53.2
No.10	1.4 MW	0.48	0.674	0.685	1156	70.17	48.2

1.5 Renewable Energy Sources in Bartica

In Bartica three (3) main sources of renewable energy were identified:

1. Photovoltaic (PV) - 1.5 MWp
2. Hydro Electric Power – 2 MW
3. Biomass – 2.8 MW

Figure 3 outlines the location of mentioned renewable sources.

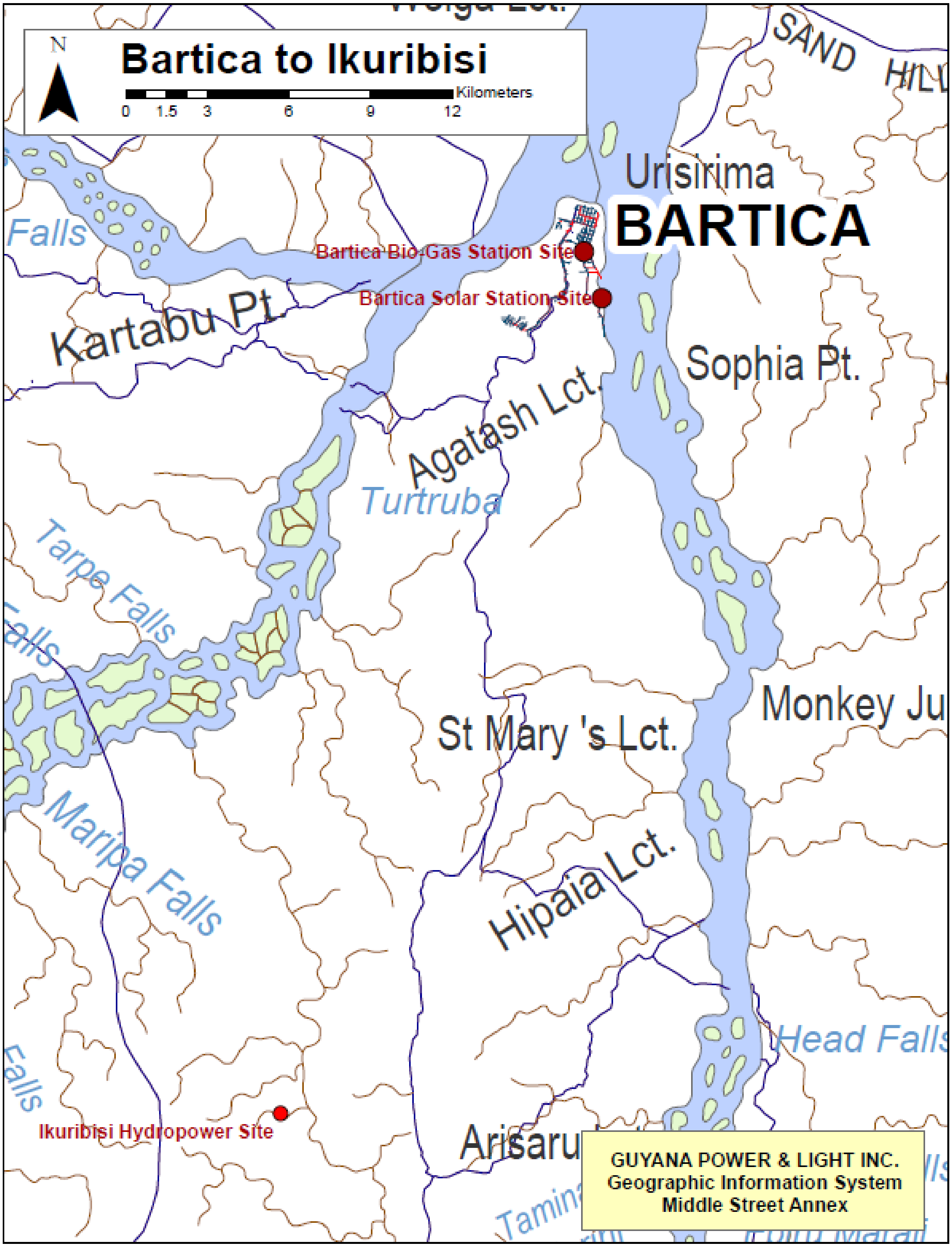

Figure 3: Location of Renewable Sources

1.5.1 Photovoltaic Resource

The Guyana Power and Light Inc. is in process of acquiring land space for the establishment of PV installation in the area of Dog Point, Agatash (main generation dispatch center). The installation will consist of a 4.2 MWhr of storage capacity (battery) and a 1MWp inverter.

This system will be integrated into the grid at this site by means of overhead lines.

It is proposed that the integration of solar energy be realized in a phase manner over a period of three (3) years as follow:

1. At the end of year 1-1 MWp
2. At the end of year 3 – an additional 0.5 MWp
3. At the end of year 9 – an additional 1.5 MWp totaling 3 MWp

1.5.2 Hydro Electric Power Resource

A hydroelectric source which has a potential of generating 2 MW of electricity was identified in the Ikuribisi river. The hydro project schedule is expected as follow:

1. At the end of the 3rd year – 1 MW
2. At the end of the 5th year- additional 1 MW totaling 2 MW

The approximate length of the transmission line between Ikuribisi and Dog Point, Agatash is 40km.

1.5.3 Biomass

It is proposed to develop a 2.8 MW biomass generating system using boilers and steam turbines. The location of such facility is yet to be determined. However, it is expected that generation commences at the end of the 5th year of the project.

2. Potential Issues and Recommendations for Grid Impact Studies

In Bartica, different methodologies have to be considered regarding potential issues relating to the grid integration of renewable energy generation. The renewable energy generations, which will feed the distribution grid must to be thoroughly analyzed.

2.1 Transmission Grid

The main grid of Bartica has an installed overall capacity of slightly more than 2 MW. The main grid is not supported by any other grids outside, which means that all active power balancing tasks have to be executed by this system.

It is proposed to establish a transmission grid in Bartica which should operate at 34.5kV. The grid should be configured such that the entire Bartica be divided into four (4) main load centres as follow:

1. Central Bartica – 5 MW
2. Mongreppo, Bydarabo, Agatash -2.5 MW
3. 4-mile – 750 kW
4. 5-mile – 750 kW

Since there will be a 40km transmission line between Ikuribisi Hydro Power Plant and the main generation dispatch centre the voltage level to transmit 2MW of electric power should not be less than 34.5kV. In addition, transient and voltage stability issues can be expected and should be studied. Also, this voltage level should become the transmission level for power between the load centres of Bartica.

With the expected penetration level of renewable energy into the isolated Bartica grid, frequency instability would become an issue especially as the demand exponentially increases. It is therefore recommended to perform studies relating to active power balancing and system flexibility as required.

These studies will aid at recognizing potential limitations to the overall penetration level of renewable generation of different technologies in the main grid of Bartica.

In addition the projects require very careful planning and design, especially with regard to an optimized coordinated control of PV, diesel generation, hydroelectric generation and biomass which will allow for maximizing the use of renewable in general.

2.3 Objectives and Contents of Proposed Studies

2.3.1 Objectives

The main objectives of studies proposed for Bartica should be the following:

On basis of realistic scenarios regarding PV, Hydroelectric Power, Biomass and Diesel Generation, system flexibility studies must be performed with the purpose of determining the maximum installed renewable energy-capacity that could be integrated into Bartica Grid.

Perform steady state and dynamic grid studies for identifying the potential renewable energy capacity that could be integrated into the proposed layout of Bartica Grid.

Perform steady state and dynamic studies for identifying necessary grid reinforcements to accommodate planned renewable generation plants in hybrid with diesel generation.

2.4 Contents

2.4.1 System Flexibility Studies

Based on scenarios being worked out on basis of:

1. Potential of PV, Hydro Electric and Biomass Power
2. Planned projects (Biodiesel, etc.)

The following grid studies are recommended:

A. Perform studies relating to active power balancing in Bartica Grid, which:
   1. Determine the residual load for various renewable energy scenarios.
   2. Compare various parameters (variability, predictability, rate of change) of the residual load with the actual load.
   3. Identify the required additional reserve power under various operating conditions for various renewable energy scenarios.
   4. Determine concepts for solar, hydro and biomass forecast for minimizing additional reserve requirements.

B. Perform short-term frequency stability studies, examining:
   1. Impact of increasing penetration of PV, Hydro and Biomass generation on system inertia and frequency performance as a result of various system contingencies
   2. Impact on primary frequency control
   3. Performance requirements for renewable energy plants and diesel power plant as it relates to the short-term performance (inertia) and impact on primary frequency control.

In addition, the following grid studies are also recommended on the basis of the 40km transmission line between the proposed hydro power plant and the dispatch centre:

2.4.2 Voltage stability studies

The impact of planned renewable energy sources on voltage stability limits of critical grid corridors, especially from the Ikuribisi hydro power plant with the 40km long transmission line should be assessed using load variation studies. In addition, the study must also determine whether reactive reinforcement is necessary and if so its location and time line for implementation and specifications.

2.4.3 Transient stability studies

Dynamic simulation studies should be performed for assessing the impact of the planned renewable energy plants on critical fault clearing times and transient stability constraints on critical transmission corridors.

3. Summary and Recommendations

The main grid of Bartica consists of 13.8kV and 4.16 kV distribution networks having an installed capacity of around 2 MW and no connections to any other power grids.

There is potential for implementing power generation from renewable energies (PV, Hydro and Biomass Power Plants).

As a result of the relatively small size of the overall system, a moderate use of the available renewable energy potential for electricity production would lead to fairly high penetration levels. Therefore, it is very important to realize studies relating to active power balancing, frequency stability issues and reactive compensation.

In addition, there will be 40km long transmission line in the proposed main transmission grid of Bartica. This will certainly require stability studies, especially transient and voltage stability studies. These studies must be realized at the planning and design stage.