
EE 492 Bi-Weekly Report 5 - sddec18-03

Design of a More Reliable Power Grid for Puerto Rico

10/23/18 - 11/5/18

Faculty Advisor: Vikram Dalal

Team Members

Logan Lillis - *Communications and Reports Lead*

Ricardo Rodriguez-Menas - *Webmaster and Project Plan Lead*

Heiqal Zamri - *Test Engineer Lead*

Pinjia Zhang - *Design Lead*

Weekly Summary

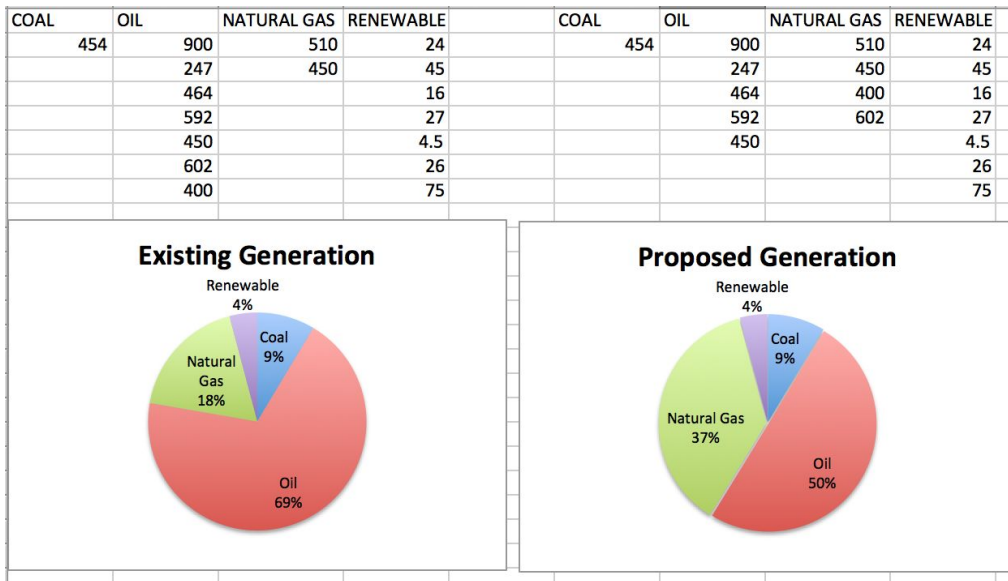
This report period began with presentations to Professor Dalal on October 23rd. The topics presented are as follows: Logan - Generation, Transmission and Distribution. Ricardo - Battery Storage and Rural Microgrids. Heiqal - Microgrids, Smart Grids, and Generators. Pinjia - Renewable Energy. After presenting, Professor Dalal discussed updates and changes needed, which are discussed in the “Pending Issues” section.. Generation, Transmission, and Distribution were decided to be nearly complete, with more research required into proposing a new LNG port. Substantially more research is required for renewables and battery storage in Puerto Rico and worldwide. The progress on microgrids is good, but a more specific plan for locating microgrids around assets is the next big step. These comments were used to update presentations for a second presentation on October 30th. At this meeting, the emphasis was numerical values, quantities, and costs for each component of the proposal. Logan presented on initial findings for a pipeline connecting San Juan and her proposed natural gas port, Pinjia presented on residential and large-scale solar, and Ricardo presented on a battery implementation in Australia.

Past Week Accomplishments

Logan:

- ❖ Presentation on Generation, Transmission, and Distribution
 - Adequate information to compose proposal
- ❖ Presentation on Natural Gas in Puerto Rico
 - LNG port off of Roosevelt Roads
 - Allows LNG access to north of island, where population center is.

- Further north than the eye of majority of Category 3+ hurricanes (whereas the proposed Aguirre port is closer to the historical major hurricane paths)
 - Shorter transmission distance by pipeline
 - Pipelines from southern Aguirre to San Juan have been denied due to environmental concerns through the center of the island)
 - Natural Gas Pipeline to San Juan
 - Approximately 50 miles by road. A direct path would be much shorter, but a national forest lies in the way.
 - Convert 2 generation facilities (Palo Seco (602MW) and San Juan (400MW) to natural gas
 - Palo Seco estimates: \$1.3B including storm hardening. San Juan Generation Plant ⅔ MW capacity of Palo Seco.
 - This conversion of 2 plants would decrease the heavy oil fuel generation to 50%
- ◆ Based on private and public generation statistics provided by PREPA and Wikipedia



Ricardo:

- ❖ Work on the project proposal for Anne Kimber.
- ❖ Research on Tesla's storage plans and recent installations (specifically in Australia)
- ❖ Study about Neoen company from France that are wind farm builders and renewable energy company.
 - Partnered up with Tesla to build wind farm and host the farm storage in Australia.
- ❖ Research on the rates and cost of energy for renewable and storage based producers.
- ❖ Sources used:
 - <https://electrek.co/2018/05/11/tesla-giant-battery-australia-reduced-grid-service-cost/>
 - https://www.washingtonpost.com/news/the-switch/wp/2017/12/26/teslas-enormous-battery-in-australia-just-weeks-old-is-already-responding-to-outages-in-record-time/?no_redirect=on&utm_term=.e575449d498c
 - <https://www.neoen.com/en/>

- <https://www.exportawards.gov.au/neoen-australia-france>
- <https://www.tesla.com/powerpack>

Heiqal:

- ❖ Initially looked at the demographic and population density of Puerto Rico to decide which locations are most important to implement microgrids. The placement and location of microgrids are very crucial depending on the density of population and also infrastructure. The locations not only must be in a radius of highly populated area but also area of where the important infrastructure are such as hospitals and water treatment centers. The microgrids are placed very closely and dense near the north east region, south region and west coast of the region. The microgrids will focus a lot on the south of the island due to how the solar panels are located a lot over there. Everywhere else has microgrids that are spread quite evenly.
- ❖ The use of oil and diesel for power generation at night and days without sun seem not optimal therefore, we are going to use natural gas and the combined heat and power (CHP) for the use of natural gas. It will not only save the consumption of natural gas, it can also produce additional energy needed for the generation.
- ❖ Sources:
 - <https://annex51.files.wordpress.com/2010/10/puerto-rico-map-2000-population-density.jpg>
 - <https://aceee.org/topics/combined-heat-and-power-chp>

Pinjia:

- ❖ Research on the implementation of solar energy resource in Puerto Rico. It is ranked from the consideration of most solar radiation, landfills area, cost comparison and so on. Puerto Rico has 17 major potential landfills. I picked up 2 of through the map to make an approximation of the landfill area and list the system cost option.
 - Aguadilla Landfill: $21,249 \text{ m}^2$ (5.25 acres)



System Type	Potential System Size (kW)	Annual Energy Output (kWh)	Annual Cost Savings (\$)	Annual O&M ^a (\$/year)	System Cost Estimates with Incentives (\$)		Simple Payback Estimates (years)	
					Assuming Lower Cost ^b	Assuming Higher Cost ^c	Assuming Lower Cost ^b	Assuming Higher Cost ^c
					Crystalline Silicon—Fixed Tilt	800	1,281,600	\$166,608
Crystalline Silicon—Single-Axis Tracking	650	1,296,419	\$168,534	\$22,750	\$2,175,000	\$4,450,000	14	31
Thin Film—Fixed Tilt	350	560,700	\$72,891	\$3,808	\$684,000	\$1,468,000	10	21

➤ Anasco Landfill: 24168m²(5.97acres)



System Type	Potential System Size (kW)	Annual Energy Output (kWh)	Annual Cost Savings (\$)	Annual O&M ^a (\$/year)	System Cost Estimates with Incentives (\$)		Simple Payback Estimates (years)	
					Assuming Lower Cost ^b	Assuming Higher Cost ^c	Assuming Lower Cost ^b	Assuming Higher Cost ^c
					Crystalline Silicon—Fixed Tilt	900	1,441,800	\$187,434
Crystalline Silicon—Single-Axis Tracking	750	1,495,868	\$194,463	\$26,250	\$2,525,000	\$5,150,000	14	31
Thin Film—Fixed Tilt	400	640,800	\$83,304	\$4,352	\$796,000	\$1,692,000	10	21

- ❖ Figure out the wind turbine major cost compare to the solar panel market price, since the wind generator may not be as popular and effective in Puerto Rico. Wind can be regarded as a side solution for those area where the shaded region appears more frequently.
 - According to NREL LAB, Bovoni, the most wind abundant city in Puerto Rico, has received the most wind in the second quarter. Also such strong wind like over 80m/s is not likely to happen as time goes by. As a result, there is a 3% margin error with respect to the technical dataset. NREL has the corrected wind speed on its site.

Table 1. USVI Corrected Annual Average Wind Speeds by Location

Observation Location	2013 Observed Annual Wind Speed @ 58 m	Long-Term Corrected Annual Wind Speed @ 58 m	
		MERRA	ERA-Interim
Bovoni Met Mast	7.41 m/s	7.17 m/s	7.20 m/s
Longford Met Mast	7.17 m/s	7.12 m/s	7.18 m/s

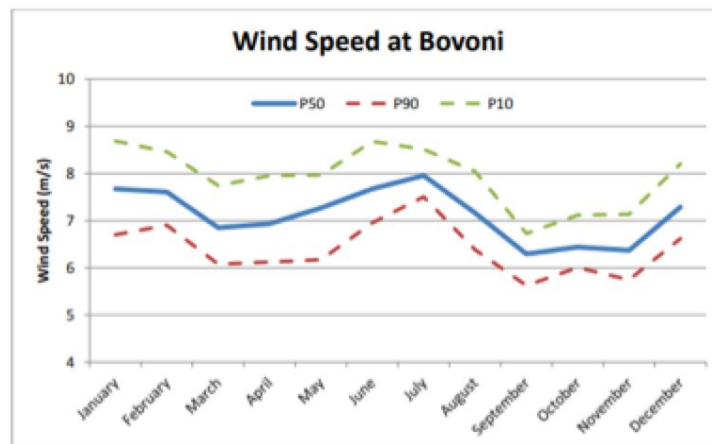


Figure 6. Monthly P10, P50, and P90 wind speeds for Bovoni

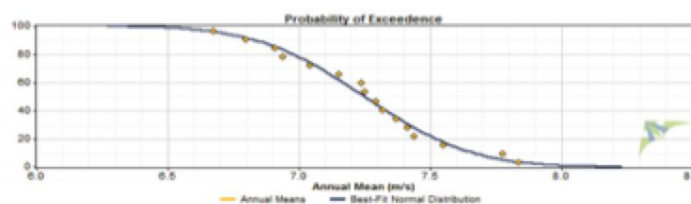


Figure 7. Bovoni annual average wind speed @ 80 meters—probability of exceedence

- ❖ The graph below represents the probability of the wind speed exceeding the value of the given period. Based on that developers plot, the measured turbulence intensity distribution graph below to represent the wind speed distribution in this area. It indicates that the down ramp of

the trend accompanied with some unexpected increase in demand for electricity may let the dispatchable generation to increase the power production at a faster rate than the normal time.

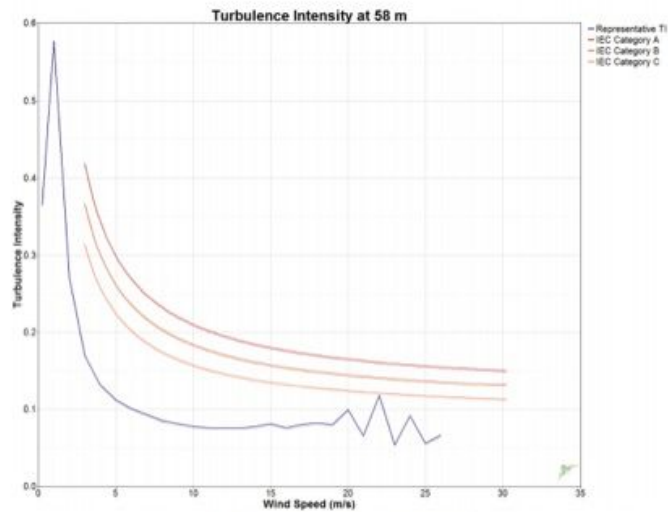


Figure 15. Bovoni measured turbulence intensity

❖ Sources:

- U.S. Virgin Islands Wind Resources Update 2014 By Joseph Owen Roberts and Adam Warren National Renewable Energy Laboratory
- <https://www.nrel.gov/docs/fy11osti/49237.pdf>
- Feasibility Study of Economics and Performance of Solar Photovoltaics in the Commonwealth of Puerto Rico By James Salasovich and Gail Mosey

Pending Issues

- ❖ Need to determine a software capable of modeling load flows and microgrids
 - Pinjia will work with power professors

- ❖ Logan:
 - Proposing a LNG deliquification port at Roosevelt Roads Redevelopment (vs. Aguirre)
 - Costs, compare proposal to Aguirre's proposal
 - Onshore vs. Offshore, Storage, etc.
 - Roosevelt Roads Redevelopment LNG terminal
 - Pipeline specifications to San Juan
 - Determine what power plants to upgrade to natural gas

- ❖ Ricardo:
 - Costs associated with battery storage
 - Compare storage implementation around the world to Puerto Rico
 - Clarify use of farms vs. distributed small storage and why
 - Breakdown of choices
 - Housing Act - Brainstorm how to get around
 - Solar water heating currently required.

- ❖ Heiqal:
 - Need to determine specific plan for locating microgrids.
 - Amount, centers, assets to protect
 - Housing Act - Brainstorm how to get around
 - Solar water heating currently required.

- ❖ Pinjia:
 - Need to compare renewable energy with worldwide market
 - Need costs of types of renewable energy
 - Need breakdown of types of renewable energy in Puerto Rico
 - Need breakdown of potentials for renewable energy in Puerto Rico

Individual Contributions

Team Member	Contribution	Weekly Hours	Total Hours
Logan Lillis	<ul style="list-style-type: none"> ● Presentations to Professor Dalal: Transmission, Distribution, Generation and Natural Gas Feasibility and Implementation Strategy ● Write Weekly Report ● Research on natural gas pipeline to northern Puerto Rico ● Research on converting power plants to Natural Gas <ul style="list-style-type: none"> ○ Costs, which in Puerto Rico ● Research on all generation facilities in Puerto Rico <ul style="list-style-type: none"> ○ MW, location, Natural Gas Feasibility 	9	34.5
Ricardo Rodriguez-Menas	<ul style="list-style-type: none"> ● Presentation to Professor Dalal: Rural Microgrids and Battery Storage ● Work with Professor Anne Kimber ● Research on Renewable Energy and energy costs <ul style="list-style-type: none"> ○ Comparing current projects around the world with possibilities in Puerto Rico 	6	41.5
Heiqal Zamri	<ul style="list-style-type: none"> ● Presentation to Professor Dalal: Microgrid Design and Distributed Generators ● Research on population density in context of locating microgrid centers ● Research on backup generators 	3	24
Pinjia Zhang	<ul style="list-style-type: none"> ● Presentation to Professor Dalal: Renewable Energy 	8	21.25

Plan for Upcoming Week

All:

- ❖ Continue to read and research further reading on Puerto Rico redesign proposals.
 - NYPA
 - CRS
 - RMI
 - FEMA
 - PROMESA
 - PREPA

Logan:

- ❖ Find cost estimations for above-ground and underground natural gas pipelines.
- ❖ Compare onshore versus offshore feasibility costs for a LNG port
 - Storage for each option
- ❖ Begin authoring generation and transmission section of proposal

Ricardo:

- ❖ Establish optimal rates for energy that we might want to use in the island.
- ❖ Find the most optimal service and continue my research/proposal for professor Kimber.

Heiqal:

- ❖ Meet up with group to fit all the pieces of the puzzle
- ❖ Look more into the use of CHP and natural gas and to understand the concept a bit more.

Pinjia:

- ❖ Complete Presentation on renewable energy
- ❖ Meet with Professor Dalal to discuss calculating costs
- ❖ Research wind energy feasibility and equipment costs