RFI 1. GPA proposes that each new Net Energy Metering Customer may elect to pay the new Energy Storage Rate, or to use a Frequency Control Capability or a new Energy Storage System with the installation of a new solar PV or wind turbine system.

A. Please explain what GPA means by "Frequency Control Capability."

GPA Response for RFI 1-A

GPA uses the term "Frequency Control Capability" to describe any technology or operational procedure that prevents significant deviation from 60 Hertz. Significant means a deviation that contributes to one or more of the following:

- Activation of underfrequency load shedding (UFLS)
- Activation of over speed tripping of generators
- Action of the Agana ESS to restore frequency back to 60 Hertz.

This meaning and context is specific and largely unique to Guam Power Authority and the characteristics of its grid. This uniqueness refers to but may not be limited to the following characteristics of the GPA grid:

- Generation mix;
- Governor response;
- System protection;
- Grid Strength;
- Load characteristics;
- System response to faults.

Activation of UFLS may be triggered in at least two ways:

- Instantaneous loss of online generation;
- Large instantaneous surge in loads.

Instantaneous Loss of Online Generation

Prior to NEM and the installation of utility-scale intermittent renewable resources into the GPA grid, GPA had only to consider the instantaneous trip of generators as a threat for cascading system blackouts remedied by UFLS.

Compared to many other power system grids, many of GPA generators are large relative to system load. When they trip, this causes a very steep frequency decay. If this frequency decay is not arrested quickly, then the system will black out.

In its Renewable Integration Project, GPA requested its consultant, Electric Power Systems, Inc., to investigate how steep GPA's frequency decay was relative to other systems. They found that GPA's system experiences the fastest frequency decay given the trip of its largest unit than any other system they investigated including the Hawaiian Island systems. Therefore, GPA must take greater measures to prevent blackouts than those systems. This means shedding more load more quickly, installing flexible generation, and commissions fast acting Battery Energy Storage Systems (BESS) for spinning reserve. These measures by themselves do not solve the problem.

UFLS brings back the balance between online generation and system load by shedding load. Please note that the design of the Agana ESS requires the system to inject power into the GPA grid in the event of a large frequency excursion within 200 milliseconds, much faster than GPA's relatively inflexible generation can.

Large PV output drop outs due to passing clouds can trigger UFLS. GPA has observed UFLS activation from PV dropouts at the Dandan facility. The nominal peak output capability for the Dandan facility is 26.5 MW.

GPA has shared many graphs of the GlidePath solar PV facility output with the PUC. These graphs show the spiky nature of the PV output. Similar graphs of NEM systems show the same characteristic spikiness. Although the outputs of the NEM system are not a 100% in lockstep with each other or the GlidePath facility, they are highly correlated. And tend in aggregate to swing together. This means when a large drop at the GlidePath facility occurs due to cloud cover, NEM systems will also experience a dropout in output. Collectively, these dropouts will likely trigger UFLs.

With the growth of NEM to 26.4 MW and the nominal 26.5 MW Dandan facility, intermittent solar PV generation is of the size of large GPA generating units. On sunny days, Solar PV may account for over 25% of GPA daytime system load. This is significant. A large dropout at high solar PV production and low loads can trigger UFLS.

In one of the General Manager's reports, John M. Benavente, PE showed that beginning with the NEM capacity attaining an aggregate capacity of 13 MW, the amount of UFLS activations have increased. These activations increased faster with each incremental increase in NEM aggregate capacity.

Large Instantaneous Surge in Loads

Power System Frequency decay will occur whenever there is more load than generation. This can occur if generation trips. It can also occur when there is a large quick surge in load too large for GPA generation to react fast enough to bring the load and generation into balance quickly enough.

This is likely not currently a problem especially if most NEM users are exporting most of the PV output during the day. However, if a large PV drop out occurs, then the NEM users will need to have their loads served by GPA instead of the NEM system. If this becomes sizeable, it may trigger UFLS. It is something GPA should keep an eye on.

B. Please describe the specific type of equipment that customers would be required to install for Frequency Control Capability.

GPA Response for RFI 1-B

There are likely several solutions to this problem. Solar PV providers and GPA should collaborate on strategies, and equipment configurations to solve these issues. GPA should not dictate specific models and makes of equipment as these change as technology and the solar PV market evolve. GPA and solar PV system providers should work collaboratively to determine solutions to this problem.

GPA has considered the following technical functional options:

- Short-Term Energy Storage;
- Non-Export Inverter Functions;
- Short-Term Energy Storage and Non-Export Inverter Functions.

GPA is also conducting studies with Utility Financial Services LLC and Landis and Gyr related to these applications. GPA will add or modify its requirements when it completes these studies.

GPA will have to tune its requirements as new systems are introduced. This is likely to require reprogramming of the inverters and other systems as GPA, solar PV providers, and customers learn from their experiences.

GPA does not have telemetry on NEM systems. GPA must rely on irradiance data to estimate the output of NEM systems. GPA does not have a sensor network for real-time solar irradiance so GPA must rely on average data published by NREL or other sources. GPA does not have a real-time information on the NEM user loads served by NEM systems. When the output of NEM systems drop, GPA must absorb and carry those loads. Therefore, GPA will require new systems to install a GPA meter between the AC output of the inverter and the customer electric service panel. The placement of this meter will depend on the specifics of the NEM system configuration and interconnection.

In the future, GPA may wish new systems to accept control signals for curtailment or other functions through the smart meter. New systems should provide the flexibility to accommodate these future requirements.

Short-Term Energy Storage Solution Requirements

GPA's functional requirement includes the following:

- The battery system capacity should match the NEM system maximum output (kW) at the AC output of the inverter;
- The NEM system inverter should be able to detect a greater than ten percent drop within one minute in PV output and immediately command the energy storage batteries to output power to the grid to sustain the original PV power output to the grid for at least 15 minutes or until the solar PV output recovers;
- The minimum energy capacity should be equal to the Energy Storage System Capacity multiplied by 0.5 hours.

This is the preferred GPA solution.

For a 5-kW NEM system, the battery capacity should be capable of supplying 5 kW and 2.5 kWh.

Non-Export (No-Export) Inverter Functions Solution Requirements

This solution does not require an Energy Storage System. However, it is constrained to customers who are largely energy exporters and do not have large day-time loads.

PV system inverters can now accommodate a non-export requirement or may be retrofitted to provide it. A non-export function will use a sensor at the distribution service line before the meter to determine if the solar PV system is exporting power to the grid. If it is, the inverter will throttle its output until there is no export of power into the grid. In order for this have benefit for GPA, the inverter must prevent the export very quickly within a few cycles. A cycle is 16.67 milliseconds.

The GPA system will not observe PV drop outs using this solution. However, if the PV system provides power to a sizable customer load, the GPA system will observe a pickup of a portion of that load. GPA should work with customers on whether this solution is appropriate for GPA and the customer.

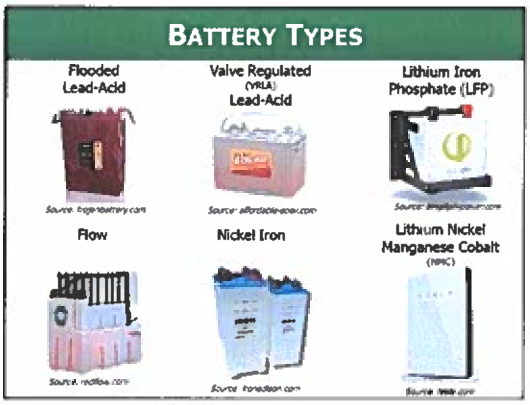
Short-Term Energy Storage and Non-Export Inverter Functions Solution Requirements

For customers who have a large loads served by their solar PV system, a drop out in solar PV output means GPA must immediately serve their loads. A large enough aggregate surge load may trigger UFLS. The battery system capacity should match the NEM system maximum output (kW) at the AC output of the inverter These customers will be required to install energy storage sufficient to sustain 75% of their peak load for up to 0.5 hours before drawing energy from the GPA system as well as perform the non-export function.

C. What are the components of "Frequency Control Capability"? Would customers be able to install different brands or types of products for Frequency Control Capability? If so, what would some of those brands or types of products be?

GPA Response

Many inverter manufacturers support export limiting or no-export functions. Some of these include Fronius, SolarEdge, and SMA. Designers many use different battery technologies for their energy storage. This should be left up to the solar PV system designers. Solar PV providers should select the appropriate equipment to meet GPA requirements.



Source: Solar Energy International PV203

Figure 1. Different Battery Technologies

GPA is not going to specify the specific system designs or equipment. GPA is going to provide the system design requirements for meeting GPA's objective to prevent triggering UFLS.

D. What would be the specific technical requirements and specifications for such Frequency Control Capability?

GPA Response

Please refer to GPA's response to RFI 1-B.

E. Would the Frequency Control Capability required for each new customer system vary based upon the size of the system, i.e., a 5 kW system versus a 25kW system? Explain how the requirements would vary based upon the size of the system.

GPA Response

Yes. the Frequency Control Capability required for each new customer system vary based upon the size of the system. Please refer to GPA's response to RFI 1-B.

F. Describe the specific type of Frequency Control Capability that a customer would be required to install for a 5 kW PV system.

GPA Response

Please refer to GPA's response to RFI 1-B.

G. Would the specific type and capacity of a Frequency Control Capability be specified in the Interconnection Agreement with the Customer?

GPA Response

Yes. GPA would also require testing as part of commissioning the system. GPA will approve the Interconnection Agreement for installation. It will require a second approval to determine if the system actually performs to GPA requirements.

H. Would the customer be required to install the Frequency Control Capability before the Interconnection Agreement was approved?

GPA Response

Yes. GPA would also require testing as part of commissioning the system. GPA will approve the Interconnection Agreement for installation. It will require a second approval to determine if the system actually performs to GPA requirements.

I. Would GPA be required to physically inspect each new NEM system before it could be operational to determine if the Frequency Control Capability had been installed and whether it was adequate to meet requirements?

GPA Response

Yes, GPA be required to physically inspect each new NEM system before it could be operational to determine if the Frequency Control Capability had been installed and whether it was adequate to meet requirements. GPA will also audit systems using smart meter data to ensure the GPA requirements are being met. GPA reserves the right to disconnect non-conforming systems.

J. Please explain what GPA means by an "Energy Storage System."

GPA Response

Article 706 of the 2017 National Electric Code has the following definitions for "Energy Storage System."

- **Energy Storage System (ESS).** One or more components assembled together capable of storing energy for use at a future time. ESS(s) can include but is not limited to batteries, capacitors, and kinetic energy devices (e.g., flywheels and compressed air). These systems can have ac or dc output for utilization and can include inverters and converters to change stored energy into electrical energy.
- **Energy Storage System, Self-Contained.** Energy storage systems where the components such as cells, batteries, or modules and any necessary controls, ventilation, illumination, fire suppression, or alarm systems are assembled, installed, and packaged into a singular energy storage container or unit
- **Energy Storage System, Pre-Engineered of Matched Components.** Energy storage systems that are not self-contained systems but instead are pre-engineered and field-assembled using separate components supplied as a system by a singular entity that are matched and intended to be assembled as an energy storage system at the system installation site.
- **Energy Storage System, Other.** Energy storage systems that are not self-contained or pre-engineered systems of matched components but instead are composed of individual components assembled as a system.

Article 706 of the 2020 National Electric Code only retains the self-contained definition for "Energy Storage System." GPA means and uses the 2017 Article 706 definition for "Energy Storage System" in this context.

K. Please describe the specific type of equipment that customers would be required to install for an Energy Storage System (ESS). What are the components of a GPA required ESS?

GPA Response

GPA is not going specify the type of equipment that customers would be required to install for an Energy Storage System (ESS). That responsibility remains with the selected solar PV provider selected by the customer. The solar PV provider has to design a system meeting the requirements set forth in GPA's response to RFI 1-B.

L. Would customers be able to install different brands or types of products for an ESS? If so, what would some of those brands or types of products be?

GPA Response

The solar PV system designer should select the brands or products or technologies used for the systems they provide customers. Please refer to Figure 1 for different battery technologies. Tesla Powerwall and Blue Planet Blue Ion self-contained energy storage are examples of self-contained small-scale ESS products.

M. What would be the specific technical requirements and specifications for such ESS?

GPA Response

GPA sets out its requirements in its response to RFI 1-B.

N. Would the ESS required for each new customer system vary based upon the size of the system, i.e., a 5 kW system versus a 25kW system? Explain how the requirements would vary based upon the size of the system.

GPA Response

Yes, the ESS required for each new customer system will vary based upon the size of the system and the type of solution chosen. Please refer to GPA's response for RFI 1-B.

O. Describe the specific type of ESS that a customer would be required to install for a 5 kW PV system.

GPA Response

Many different kinds of battery system types can meet GPA's requirements. Please refer to GPA's response to RFI 1-B.

P. How would the size of a required ESS be determined for each customer?

GPA Response

Please refer to GPA's response to RFI 1-B.

Q. Would the specific type and capacity of an ESS be specified in the Interconnection Agreement with the Customer?

GPA Response

Yes.

R. Would the customer be required to install the ESS before the Interconnection Agreement was approved?

GPA Response

GPA will approve the Interconnection Agreement for installation. It will require a second approval to determine if the system actually performs to GPA requirements. This will involve a GPA physical inspection and the analysis of metered data.

S. Would GPA be required to physically inspect each new NEM system before it could be operational to determine if the ESS had been installed and whether it was adequate to meet requirements?

GPA Response

GPA will approve the Interconnection Agreement for installation. It will require a second approval to determine if the system actually performs to GPA requirements. This will involve a GPA physical inspection and the analysis of metered data.

T. What storage capacity for a 5 kW PV system would be required?

GPA Response

When using the Short-Term Energy Storage Solution option:

If the AC output of the inverter is 5 kW, the ESS minimum requirements are 5-kilowatts and 2.5 kilowatt-hours.

When using the Non-Export (No-Export) Inverter Function option:

No ESS required

When using the Short-Term Energy Storage and Non-Export Inverter Function option

First, determine customer peak daytime demand over the past 12-month period. If not available, use full output of the AC side of the inverter to compute the ESS energy requirement.

The battery system capacity should match the NEM system maximum output (kW) at the AC output of the inverter. The energy storage minimum energy requirement is 75% of their peak load for up to 0.5 hours before drawing energy from the GPA system as well as perform the non-export function.

For a system with no metering history, the energy storage sizing is 5-kW and 1.875 kWh.

U. For what period of time would each ESS be required to store energy?

GPA Response

Please refer to GPA's response to RFI 1-B.

V. What size ESS would be required for a 25kW system?

GPA Response

When using the Short-Term Energy Storage Solution option:

If the AC output of the inverter is 25 kW, the ESS minimum requirements are 25-kilowatts and 12.5 kilowatt-hours.

When using the Non-Export (No-Export) Inverter Function option:

No ESS required

When using the Short-Term Energy Storage and Non-Export Inverter Function option

First, determine customer peak daytime demand over the past 12-month period. If not available, use full output of the AC side of the inverter to compute the ESS energy requirement.

The battery system capacity should match the NEM system maximum output (kW) at the AC output of the inverter. The energy storage minimum energy requirement is 75% of their peak load for up to 0.5 hours before drawing energy from the GPA system as well as perform the non-export function.

For a system with no metering history, the energy storage sizing is 25-kW and 9.375 kWh.

W. How would GPA monitor whether, after the NEM customer installs a Frequency Control Capability or an ESS, and whether each system is functioning?

GPA Response

The customer must install a meter between the AC output side of the inverter and the customer service panel. The placement of this meter will depend on the specifics of the NEM system configuration and interconnection.

GPA will test the system for compliance using the metered data from the customer meter and the inverter meter. GPA will likely charge the customer for this service.

RFI 2. Please provide a copy of the Joint Renewable Integration Study (RIS) that is referred to in the Petition.

GPA Response

GPA has been advised by its Joint Renewable Integration Study (RIS) partner, the United States Department of the Navy, that GPA should not make study and similar studies public as doing so may provide bad actors information on the vulnerabilities of the GPA system. Please refer to the attachment *Transmission System Study.pdf* used as part of GPA's 2021 Integrated Resource Planning Stakeholder Panel briefings.

RFI 3. Please provide a copy of the Energy Storage Rate Schedule.

GPA Response

GPA is currently undertaking a study with utility Financial Services LLC to determine the Energy Storage Rate Schedule.

RFI 4. Please provide any transcript, minutes or other record of the stakeholder outreach meeting conducted by GPA on February 9, 2020.

GPA Response

Joyce to Provide

RFI 5. In GPA Docket 19-04, the PUC order GPA to include the following language in its tariff:

However, when the capacity of Customer-Generator installations on the GPA system exceeds an aggregate kW cap (10%) of the utility's system peak demand (261 MW), the PUC will review the net metering program, determine whether the NM Rider should continue to be offered for new "net metering" customers, and consider whether any adjustments should be made to compensation rates paid by GPA to customer-generators for capacity generation.

Since GPA currently estimate 24 MW of net metering capacity, which is below the 10% cap of the utility's system peak demand, does GPA consider the requested Energy Storage Rate an alteration of compensation rates paid by GPA to net metering customers?

GPA Response

NEM penetration is currently above the 26.1 MW cap.

RFI 6. In GPA Docket 19-04, the PUC ordered GPA to complete "the planned distribution system impact study and include in that study a balanced locational and full benefit-cost analysis of how distributed generation impacts the distribution system". Has GPA completed the distribution impact study? If so, please provide a copy to PUC.

GPA Response

GPA is currently undertaking a distribution study with Landis and Gyr. GPA is also currently undertaking a study with Utility Financial Service LLC to investigate rates associated with NEM and addressing rates considering the locational value of solar and technically and economically feasible non-wires alternatives to solve distribution problems identified in the distribution study. Please refer to the attachment *Distribution System Plan.pdf,* a briefing presentation for GPA's 2021 Integrated Resource Planning Stakeholder Panel.

RFI 7. In GPA Docket 19-04, the PUC ordered GPA "to include a rebate program for battery storage in the DSM program and encourage solar providers to include storage with the solar systems and explain the benefits to customers." Has GPA done so? If so, please provide details of participation, including number of rebates awarded and any available information on battery capacity and type. Wouldn't such a rebate potentially reduce system instability and intermittency by encouraging providers to include battery storage in NEM systems?

GPA Response

No. GPA has not done so. In the last PUC hearing regarding DSM Energy Sense Rebate Program funding, GPA and the PUC agreed to focus on rolling out new residential and commercial lighting and air conditioning rebate programs. GPA has not funded the battery storage pilot study that will be used to design the battery rebate program. This funding will have to be authorized out of LEAC funds set aside for DSM related studies.

Such a rebate potentially may or may not reduce system instability on the GPA system. The efficacy of using NEM systems on the Guam system to reduce system instability will require a study and pilot programs specific to Guam.

Battery storage without solar PV may be used to reduce demand charges for large customers. GPA will investigate this application for designing a rebate program for batteries.

GPA will also perform a similar pilot as Hawaiian Electric Company. Hawaiian Electric has a pilot program with SunRun. "Beginning in 2020 and continuing through at least 2024, Sunrun and OATI will send the energy generated by rooftop solar panels and stored in approximately 1,000 Brightbox home batteries on O'ahu to the electric grid during times of high electricity demand when called upon by Hawaiian Electric. Sunrun's Brightbox battery systems will also send stored solar energy to the grid when there is high energy demand or high-risk of power outages, safeguarding against blackouts and providing reliable, stable power to O'ahu residents."[1] Please note that at the current NEM rider, energy provided by NEM systems is several times more costly than obtaining the same energy from GPA's Phase II and Phase III projects when completed.

GPA SPORD and GPA E&TS manpower commitments to FY 2021 projects mean that GPA may start these pilots and studies beginning February 2022 with funding identified from LEAC. The pilots would likely run a year.

RFI 8. PA indicates that new NEM Customers will have the option of either installing Frequent Control Capability or an ESS, or paying a monthly fee or charge to GPA of $2.43 per kW per month, as installed.

A. Please explain in detail how GPA determined that the appropriate Energy Storage Rate is $2.43 per kW per month. How much annual revenue will GPA obtain from such rate? Provide any projections of revenue that GPA has prepared. Specify each cost or expense that such rate is intended to compensate GPA for.

GPA Response

John Kim to provide

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[1] GlobeNewswire. (2019). Sunrun To Help Power Hawaii With Rooftop Solar and Battery Network. URL: https://www.globenewswire.com/news-release/2019/09/04/1910732/0/en/Sunrun-To-Help-Power-Hawaii-With-Rooftop-Solar-and-Battery-Network.html (Accessed March 20, 2021)

B. Will the revenues collected from the Energy Storage Rate be used by GPA to install Frequency Control Capability and/or ESS?

GPA Response

Yes. It will also be used to fund a Grid Controller System to control and manage ESS, solar PV, and conventional generation.

C. Attach all documents, reports, schedules, or written materials which set forth how the proposed Energy Storage Rate was determined.

GPA Response

John Kim to provide

RFI 9. Do any states in the United States have a similar requirement that NEM Customers either install Frequency Control Capability or ESS, or otherwise pay a monthly Energy Storage Rate? If so, please identify such states and provide any relevant materials that GPA has concerning the programs in such states.

GPA Response

For the State of Hawaii Investor Owned Utilities (IOU), NEM was closed in October of 2015. Hawaiian Electric Company (HECO) Distributed Energy Resource (DER) Programs are listed in Table 1 below.

Table 1. HECO's Distributed Energy Resource (DER) Programs

HECO DER Program	Description
Customer Grid-Supply Plus (CGS Plus)	Systems must include grid support technology to manage grid reliability and allow the utility to remotely monitor system performance, technical compliance and, if necessary, control for grid stability.
Smart Export	Customers with a renewable system and battery energy storage system have the option to export energy to the grid from 4 p.m. – 9 a.m. Systems must include grid support technology to manage grid reliability and system performance.
Customer Self-Supply (CSS)	Is intended only for private rooftop solar installations that are designed to not export any electricity to the grid. Customers are not compensated for any export of energy.
Customer Grid-Supply (CGS)	Participants receive a PUC-approved credit for electricity sent to the grid and are billed at the retail rate for electricity they use from the grid. The program remains open until the installed capacity has been reached.

Please refer to the attachment *Oahu Programs at a Glance.pdf* for the HECO DER Program details.

Kauai Island Utility Cooperative ended net metering in 2008. It has put into place many the same things GPA is undertaking such as utility scale solar PV, utility scale solar PV plus battery energy storage systems, utility scale energy storage systems for grid regulation, and dispatchable solar PV plus BESS power plants.

RFI 10. If GPA has calculations as to the monetary benefit for NEM Customers regarding use of the GPA grid, please provide all such calculations to the PUC.

GPA Response

John Kim to provide

RFI 11. At present there are an estimated over 24MW of net metering capacity. Although Resolution No. 2020-01 refers to the 25MW utility-scale solar PV farm as resulting in significant intermittency which the resolution states degrades the reliability of the island wide power system, should NEM customers pay for instability of the 25MW PV farm when it was GPA that contracted for the construction of such farm and did so without provision for battery storage?

GPA Response

Currently, NEM capacity is over 26.1 MW the PUC cap.

All customers should pay for the Agana and Talofofo BESS. These costs are already embedded in the base rate. Please note that these systems also benefit NEM customers, especially the Agana BESS.

Phase III and subsequent Phase IV Renewable Acquisition projects will also have BESS that can contribute to frequency regulation and droop response. These will also help remediate the problems NEM customers in aggregate pose to grid stability. NEM customers would be a free rider on expenses borne by non-NEM customers for benefits that allow them to operate on GPA's grid. Consider the following at high intermittent renewable energy penetration:

- During peak solar production times the energy produced may need to be stored for later use why should non-NEM customers pay for these storage systems to accommodate excess NEM production?
- California and Germany may pay renewable energy providers to curtail excess renewable energy or pay neighboring states to take the energy otherwise the excess generation may cause system instability. Guam has no undersea power cables to perform the latter. Additionally, why should non-NEM customers pay to curtail their less expensive solar PV contracts instead of the more expensive NEM energy?
- At high intermittent renewable energy penetrations, GPA may have to lower the outputs of their most efficient generation units to accommodate NEM in addition to GPA solar PV. This means these generation units will be producing power less efficiently. Most of these additional costs will be paid by non-NEM customers.
- At high intermittent renewable energy penetrations, GPA may have to shut down conventional generation and run synchronous generators otherwise, the PV inverters will stop working.

RFI 12. GPA already has pending contracts for the construction of 120MW of solar power by KEPCO and Hanhwa. The 120MW of solar plant will have very little solar storage capacity. Is it fair to charge NEM customers for the impact of 24MW of net metering solar capacity, when no extensive Frequency Control Capability or ESS are planned for the 120MW plants?

GPA Response

The Phase II systems use BESS to shape and firm their intermittent solar PV outputs so that they do not adversely impact system stability. GPA is also negotiating for additional BESS capacity for participation in system frequency regulation. Therefore, the question is not relevant.

The Phase II Renewable Energy Contracts for KEPCO and Hanwha comprising the 120MW referred to in thi RFI include Battery Energy Storage Systems (BESS) for the purpose of mitigating the variability and intermittency from these PV systems caused by solar radiation conditions (e.g., shading caused by fast moving clouds). GPA made it a requirement in the rebid of Renewable Energy Resource Phase II (Multi-Step Bid GPA-070-16) to have energy storage system (ESS) for ramp rate control to address the power grid instability caused by high renewable source penetration such as PV solar. These new projects will have batteries functioning similar to what the Talofofo BESS system is now providing to GPA to address the output from the Dandan Solar Facility. In addition, for the Hanwha contracts, additional batteries are to be installed to shift approximately 15 MW from their total 60 MW contracted capacity for delivery at night due to interconnection restrictions. This shift reduces the actual intermittency potential from the Hanwha projects.

The BESS in all contracts are required to be operational for commissioning and operation of the solar plants. The 120MW solar power plants being constructed by Hanwha and KEPCO will be outfitted with total of 97 MWh of ESS capacity. These ESS systems are designed to provide power grid support either ramp rate control (smooth out the fluctuation output of the solar PV plants caused by solar radiation conditions (e.g., shading caused by moving clouds)) or load shifting.

RFI 13. Are NEM Customers responsible for the intermittency caused by the 25MW Dandan utility scale solar PV farm? Does the Dandan PV farm have any relevance to the energy storage rate that NEM customers should pay? Please explain why the alleged intermittency of the solar PV production of the Dandan solar PV farm is relevant to whether NEM Customers should have Frequency Control Capability or an Energy Storage System?

GPA Response

This question is irrelevant. The Talofofo BESS remediates the intermittency of the Dandan 25.6 MW solar PV facility. The Talofofo and Agana BESS system costs are embedded in the ratebase. They are largely being paid for by non-NEM customers. Why should non-NEM customers pay for impacts of NEM customers?

RFI 14. What evidence does GPA have that the 24MW of solar energy produced by NEM Customers has directly caused intermittency to the island's power grid? Please provide all data, analyses, memorandums, and studies demonstrating the root cause analyses for the conclusion stated in the resolution.

GPA Response

Please refer to Guam RFI 14 UFS summary 03-22-2021.pdf provided by UFS.

RFI 15. GPA claims that as of October 31, 2019, GPA customers had experienced 27 feeder trips or outages due to solar PV systems without ESS or Frequency Control Capabilities. Please provide the root cause analyses documenting this conclusion. Which trips or outages were caused by NEM systems and which were caused by the Dandan farm? What evidence does GPA have that these trips or outages were caused by NEM systems?

GPA Response

The trips would have collectively been triggered by NEM and the Dandan solar PV facility together. With no telemetry of NEM systems, GPA relies on PV dropouts experienced at the Dandan solar PV facility. IF Dandan is experiencing a large PV dropout due to cloud cover, NEM systems throughout Guam are likely experiencing similar drop outs in production.

RFI 16. Will the 120MW of solar energy in Phase II Renewables, without significant battery storage, result in outages or intermittency in the GPA power grid?

GPA Response

It is not highly likely. The Phase II systems use BESS to shape and firm their intermittent solar PV outputs so that they do not adversely impact system stability. GPA is also negotiating for additional BESS capacity for participation in system frequency regulation.

The 120MW of solar energy in Phase II Renewables include Battery Energy Storage Systems (BESS) as required in the renewable energy bid. GPA's latest bid, Phase III, required all renewable energy from the Solar PV projects to have energy storage systems to store all production and deliver during the evening after solar production hours. Shifted energy is firm energy as it is dispatched at a set output. This bid is unfortunately under protest but received several competitive bids that met the requirements.

RFI 17. Please explain what is meant by "Short-Circuit Ratio (SCR)", what equipment is entailed, and how it functions.

GPA Response

Short Circuit Ratio is the ratio of online available Short Circuit MVA to the installed inverter-based capacity. Short Circuit MVA is available from online synchronous generation or from synchronous condensers. Power system strength is characterized by the available fault current at a given location or by the short circuit ratio. A weak grid has an SCR of five or less. GPA studies have recommended keeping an SCR of at least two and requiring invert-based generation to operate at that level.

Please refer to the attachment, *Necessity of a Road Map Toward a Reliable Inverter-Based Generation Dominated Power System.pdf.* This article is a good tutorial on SCR and why it matters to inverter-based generation:

> "Almost all commercially-available inverter-based generation resources today require sufficient strength from the system to which they are interconnecting for reliable operations. These generation resources are called "grid-following" resources. At present, system strength is maintained by synchronous generators. However, during system conditions with high penetrations of inverter-based generation, the synchronous generators necessary to maintain system strength may not be online."[2]

[2] Matevosyan, J. & Huang, F. – ERCOT. (2019) Necessity of a Road Map Toward a Reliable Inverter-Based Generation Dominated Power System. URL: https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/ (Accessed March 20, 2021)

At 100% solar PV operation during the day at KIUC, KIUC places synchronous generation offline and runs a synchronous condenser to provide the short circuit MVA.

Additionally, consider:

> "Keeping synchronous generation online strictly to maintain system strength or inertia while this generation is not required for energy is uneconomic. Installing synchronous condensers to maintain system strength and/or inertia has been used as an alternative solution in some regions, but it also is costly and may result in additional technical challenges if many of these devices are concentrated in parts of a system."[3]

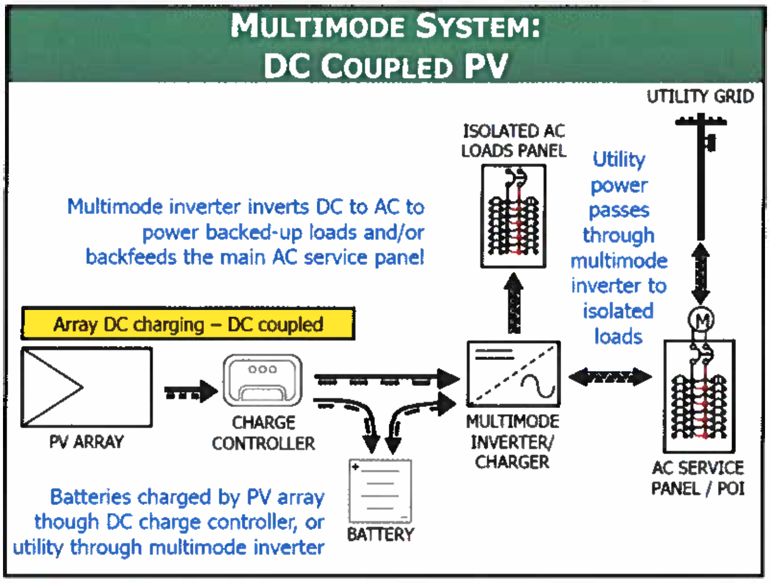
RFI 18. Resolution No. 2020-01 states: "... the PV systems and the energy storage should share the same DC Bus configuration behind one inverter system to reduce SCR burden on GPA and reduce the PV ramping affects due to intermittent solar irradiation...". Please provide a more detailed explanation of the meaning of the last sentence.

GPA Response

SCR is the ratio between system Short Circuit MVA and the combined MVA of inverter-based generation. The more inverter-based generation, the greater the need for additional Short-Circuit MVA to keep a sufficient SCR for safe and reliable operation of these inverters. DC-coupled systems connect the DC output directly to the DC input of the inverter. Thus there is one inverter for the system. AC-Coupled Systems will have a Multimode Inverter and a Grid Tied Inverter. This increases the amount of inverter MVA in the power system.

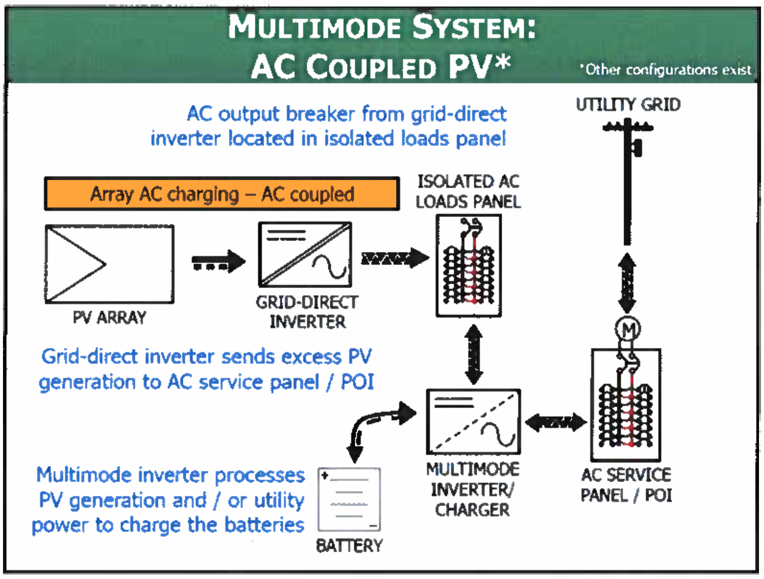
---

[3] iBid



Source: Solar Energy International PV203

Figure 2. DC-Coupled System Example



Source: Solar Energy International PV203

Figure 3. AC-Coupled System Example

The Grid-Tied Inverter can provide power into the grid through the multi-mode inverter. The power output would include intermittency. Having the inverter run off the batteries can eliminate intermittent outputs into the grid.

RFI 19. Is it inconsistent for GPA to require Frequency Control Capability or ESS on new NEM systems, but not to require the same for the as yet unconstructed 120MW solar plants? If not, why not? Won't intermittency or instability caused by the 120MW plants be greater than that caused by 24MW of net metering capacity?

GPA Response

No. The Phase II projects will use BESS to smooth out intermittencies including PV output drop outs. This question is irrelevant because GPA is requiring the Phase II projects to ameliorate intermittency and PV drop outs.

Please refer to Figure 4. The Talofofo BESS remediates the intermittent output of the Dandan solar PV facility using battery energy storage system and system controller. The intermittent output of the Dandan facility is smoothed out (blue line) including the PV output drop outs.

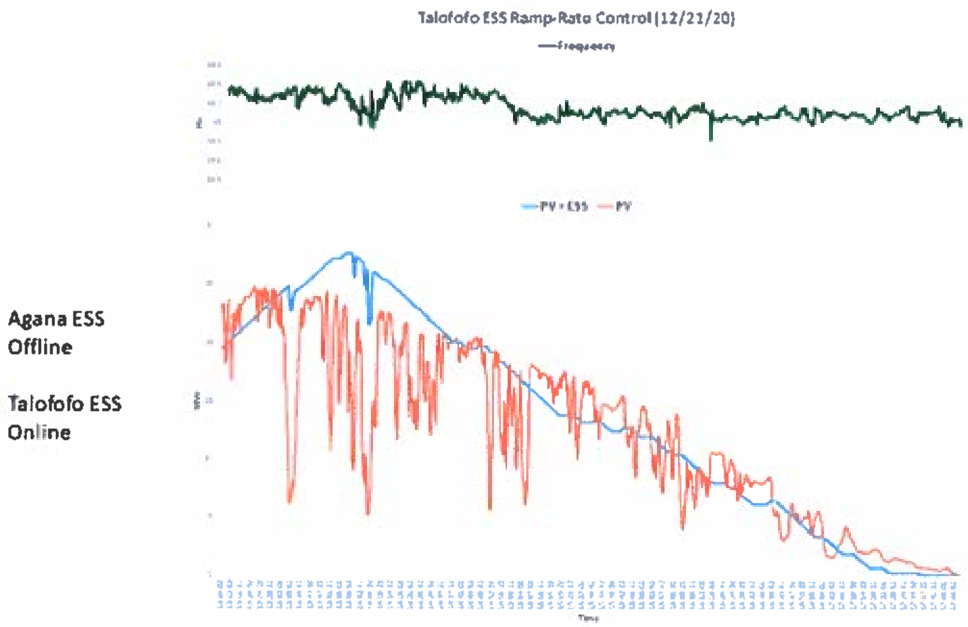


Figure 4. Talofofo BESS Performance

RFI 20. Has GPA quantified the alleged cost to non-NEM Customers from NEM systems? If so, please provide any documents or materials supporting this conclusion and that relate to costs to non-NEM Customers from PV systems without Frequency Control Capability or Energy Storage Systems.

GPA Response

Please refer to Guam RFI 20 UFS summary 03-22-2021.pdf provided by UFS as a partial answer to this RFI.

GPA is working with Utility Financial Services on a study to that will fully answer the questions posed in this RFI. GPA will provide this study when completed.

Distribution System Study

History of GPA Medium Range Distribution Planning

- GPA performed a comprehensive medium range distribution study in 1992 and in 2010 under the Engineering Department.
- The responsibility for this study was reorganized under the Strategic Planning & Operations Division in 2020.
- Under this arrangement, both SPORD and the Engineering Distribution Section will work on the study. SPORD will take primary responsibility for the study. Engineering will provide valuable insights into distribution system operations as well as document ad hoc distribution planning.

Project Partners

- Internal GPA Team
  - AGMETS
  - Engineering/Distribution Section
  - Engineering/Real Estate Section (GIS)
  - Engineering/Transmission Section
  - SPORD/System & Smart Grid Planning Section
  - SPORD/Strategic Planning & Energy Contracting Section
  - SPORD/Demand-Side Management & Green Programs Section
  - Information Technology Division
  - Chief Financial Officer (Rates)
- External Team
  - Landis & Gyr (L+G)
  - Utility Financial Solutions LLC (UFS)

Distribution Study Scope Using Advanced Grid Analytics (L+G)

Priority	Tasks
1	One (1) AGA System Assessment
2	Distribution Model Corrections Study (via AGA Network Model Validator)
3	Load Flow Studies (via AGA Asset Loading)
4	Distributed Renewable Energy Intermittency and Voltage Issue Elimination/Management Study (via AGA Planning Case Studies)
5	System Wide Voltage Analysis Study (via AGA Voltage Visualization)
6	Volt/VAR Optimization Study (via AGA Planning Case Studies)
7	Conservation Voltage Reduction Study (via AGA Capacity Contribution as well as Voltage Visualization and Planning Case Studies)
8	Demand Response Study (via AGA Capacity Contribution and Planning Case Studies)
9	Automated Switching and Communicating Fault Circuit Indicator Study (via GIS model analysis)
10	One (1) electronic document that catalogs all distribution design studies that were completed for this SOW and for future reference.

UFS Scope

- Address May 30, 2019 PUC Order, GPA Docket 19-04, Guam Power Authority Request For Modification Of Current Net Metering Rider [NEM]

PUC Order Items (GPA Action Items)

PUC Order Item #	PUC Order Provision
6	GPA may petition the PUC for further changes to the NM Rider, including the rate of compensation paid to net metering customers, prior to the time at which the aggregate KW cap (10%) of the utility's system peak demand is met, but only if it has met all of the following preconditions
7	GPA is ordered to complete the planned distribution system impact study and include in that study a balanced locational and full benefit-cost analysis of how distributed generation impacts the distribution system.
8	GPA is ordered to include a rebate program for battery storage in the DSM program and encourage solar providers to include storage with the solar systems and explain the benefits to customers
9	If GPA is concerned about lost revenue, it should provide appropriate evidence during its next filed base rate case

Prerequisites for GPA to Petition (Item #6)

- GPA may petition the PUC for further changes to the NM Rider, including the rate of compensation paid to net metering customers, prior to the time at which the aggregate KW cap (10%) of the utility's system peak demand is met, but only if it has met all of the following preconditions:
    1. The distribution system impact study which GPA has already planned shall be completed;
    2. GPA shall have conducted and completed a full, balanced benefit-cost analysis that analyzes all of the impacts distributed generation has on the distribution system, especially specific to the location of the distributed generation on the system;
    3. A third-party consultant, undertakes and completes an independent study determining the cost of grid and other services used by NEM customers and which identifies, in detail, the specific value of those services to the NEM customers.
    4. The studies referenced in (2) and (3) above shall only be undertaken upon joint approval of the PUC and GP A, and shall be undertaken at the expense of GP A

PUC Order

- Item #7 covered under item #6 (Repeated text within item #6)
- GPA is ordered to include a rebate program for battery storage in the DSM program and encourage solar providers to include storage with the solar systems and explain the benefits to customers (Item #8);
- If GPA is concerned about lost revenue, it should provide appropriate evidence during its next filed base rate case (Item #9).

Distribution Study Tasks Mapped to PUC Order

Priority	Tasks	May 30, 2019 PUC Order Item			
		Item #6	Item #7	Item #8	Item #9
1	One (1) AGA System Assessment	x			
2	Distribution Model Corrections Study (via AGA Network Model Validator)	x			
3	Load Flow Studies (via AGA Asset Loading)	x	x		x
4	Distributed Renewable Energy Intermittency and Voltage Issue Elimination/Management Study (via AGA Planning Case Studies)	x	x		x
5	System Wide Voltage Analysis Study (via AGA Voltage Visualization)	x	x		x
6	Volt/VAR Optimization Study (via AGA Planning Case Studies)	x			x
7	Conservation Voltage Reduction Study (via AGA Capacity Contribution as well as Voltage Visualization and Planning Case Studies)	x			x
8	Demand Response Study (via AGA Capacity Contribution and Planning Case Studies)	x	x	x	x
9	Automated Switching and Communicating Fault Circuit Indicator Study (via GIS model analysis)				x
10	One (1) electronic document that catalogs all distribution design studies that were completed for this SOW and for future reference.	x	x	x	x

UFS versus L+G Distribution Study Scope

- General outputs that UFS would like to see from the engineering study:
  1. Capital improvement plan as detailed as possible for next 1 – 5 years or longer.
  2. Identify specific improvement, asset type, reason for needed improvement, asset cost, expected year(s) when money will be spent
- Distribution Study will at a minimum identify:
  1. Multi-pronged approach to address underfrequency load shedding events.
  2. Multi-pronged approach to smooth generation and load. ("flatten the curves")
  3. Multi-pronged approach to meet the carbon neutral / carbon free plans for GPA.
     - Suggest adopting GPA Carbon goals of 50% Reduction in CO@ emissions from 2020 levels by 2035.
  4. Most of these are addressed in Renewable Integration Study at the Transmission Level.
- UFS will need to spend some more time refining inputs and outputs and UFS points of involvement throughout the engineering study

UFS Recommendations for Initial Study

UFS Recommendations on Engineering Feeder Study			Substation
Feeder	UFS Notes	UFS Priority	
P-220	Has larger array installed; Has higher total Solar PV installed	1	Apra
P-322	Has high total solar PV (small max feeder)	2	Pagat
P-087	Has larger array installed; Has highest penetration total Solar PV KW installed	3	Dededo
P-401	Has highest average sized solar PV installed (multiple 100 KW systems)	4	San Vitores

Distribution Study

- L+G Contract based on Investigating Distribution System on a Substation basis. (Phase I: 21 Feeders)

Substations	Apra	Pagat	Dedede *	San Vitores	Yigo*	Harmon
Feeders	P-220	P-321	P-87	P-400	P-330	P-046
	P-221	P-322	P-88	P-401	P-331	P-047
	P-222	P-323	P-89	P-402	P-332	P-111
	P-223			P-403		P-112

* Dededo & Yigo Feeders are the fastest NEM growth feeders.

RED Text Feeders chosen specifically for NEM Rate Study

Time Frame for Distribution Study

- For each substation analysis, the various tasks from end-to–end will take five months or less: June 30, 2021
- GPA & L+G will perform the substation analysis tasks in parallel for all substations

Ad Hoc Distribution Planning Scope

- The Ad Hoc Distribution Planning Scope includes analysis and planning for:
  - Distribution System Losses and Unaccounted-for Energy (UFA);
  - Distribution Automation (DA);
  - Microgrids.

System Losses and Unaccounted-for Energy (UFA)

- In 2010, the PUC approved GPA's Quality Management Plan for Cost Effective Reduction of System Losses and Unaccounted for Energy
- This plan recommended creating a metering network to trace system power at several key points:
  - A. Generator-Side of Generator Transformer
  - B. 13.8 KV side of the Substation Transfomers into the Distribution System
  - C. Customer Meter
- A – B = Transmission System Losses
- B – C = Distribution System Losses
- Without this system, GPA depends on Accounting Billing Information to compute System Losses. Accounting Billing Data is not accurate enough for Energy Losses Accounting because for a number of reasons.
- GPA now has very accurate data to better allocate resources to reduce system losses and verify that its loss reduction measures are effective

Distribution Automation

- Umatac Poletop Recloser Pilot Project
  - Problematic circuit experiencing numerous outages
  - GPA placed the Umatac recloser under SCADA remote control using GPA's wireless mesh network
  - Reduces most outages from one hour or more to five minutes
- Current focus is extending control to poletop reclosers
- Future projects
  - Extend remote control capability to poletop and vault switches, street light controllers, distribution transformer monitoring
- Smart Grid systems installed under GPA's ARRA grant significantly reduce costs to implement distribution automation.

Recloser Automation Projects

POLE#	ISOLATION SWITCH PAIR	POLE#	FEEDER 1	FEEDER 2	INSTALL DATE	SYSTEM DATE*
27002	13-341A	26853	P-341	P-341	7/1/2019	3/9/2021
39572	13-223A	SAME	P-223	P-341	12/15/2020	3/9/2021
37559	13-261	37560	P-261	P-261	8/3/2020	3/9/2021
	13-090		P-260	P-220	PENDING	
24260	13-210A	SAME	P-211	P-250	11/10/2020	3/9/2021
46340	13-320T332	SAME	P-332	P-320	2/19/2021	3/9/2021
	13-301	39178	P-301	P-262	PENDING	3/9/2021
	13-202A		P-202	P-251	PENDING	3/9/2021
	13-212		P-212	P-253	PENDING	3/9/2021

Microgrids

- GPA has performed the preliminary scoping and planning for several microgrids:
  - Phase III Renewable Acquisition Multi-Step Bid
    - Naval Base Guam (NBG)
    - South Finegayan
  - Umatac Substation
  - Talofofo Substation
  - Apra Substation.
  - North-Central Guam Microgrid

L+G Scope of Work

- We verifying system information to get the most accurate model of the distribution system.
- AGA gets its model configuration from the GPA GIS system. AGA checks if there are issues with the GIS model and suggests corrections based on metering data. For example, AGA can tell us if a customer is wrongly assigned to a particular transformer and the correct transformer the customer is on.
- L+G remarked, in their experience, that GPA's GIS is already more accurate than the GIS of most of their clients prior to model verification.

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Necessity of a Road Map Toward a Reliable Inverter-Based Generation Dominated Power System

January 7, 2019 by Julia Matevosyan & Fred Huang - ERCOT
(https://www.esig.energy/author/julia-matevosyan-fred-huang-ercot/)

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Regions such as Hawaii, South Australia, Ireland and Texas have recently experienced significant growth of inverter-based renewable generation, mainly wind and solar, and are now operating with very high instantaneous penetration in excess of 50-60%. As this penetration increases globally, several regions have identified limitations and challenges which indicate that it may not be feasible to maintain the desired level of system reliability with extremely high penetration of inverter-based generation using current technology. Among many identified limitations and challenges such as system inertia and ramping, system strength is one major challenge that needs to be addressed to maintain reliable operations with inverter-based generation. System strength refers to the ability to maintain stable voltages throughout the network during normal operations and disturbance conditions. In systems dominated by synchronous generators, system strength is characterized by the available fault current at a given location or by the short circuit ratio. Almost all commercially-available inverter-based generation resources today require sufficient strength from the system to which they are interconnecting for reliable operations. These generation resources are called "grid-following" resources. At present, system strength is maintained by synchronous generators. However, during system conditions with high penetrations of inverter-based generation, the synchronous generators necessary to maintain system strength may not be online.

One topic discussed in last month's blog was the critical inertia required in ERCOT based on the current system conditions and operational practice, which allows the system operator to start additional synchronous generation to maintain the needed level of inertia. Similar minimum inertia constraints are set, for example, in Ireland and South Australia. Additionally, ERCOT limits inverter-based generation output from the Texas Panhandle to maintain the necessary system strength in that area. Australian Electricity Market Operator (AEMO) requires transmission service providers to maintain pre-defined minimum system strength at designated buses on the system. Keeping synchronous generation online strictly to maintain system strength or inertia while this generation is not required for energy is uneconomic. Installing synchronous condensers to maintain system strength and/or inertia has been used as an alternative solution in some regions, but it also is costly and may result in additional technical challenges if many of these devices are concentrated in parts of a system.

Continuing to increase the amount of inverter-based generation in a system may not be feasible or economical if a certain amount of synchronous generators need to be committed or new synchronous condensers need to be installed only to provide the minimum system strength needed. Additionally, different equipment manufacturers may have different system strength requirements, and the increasing stability constraints and coordination among resources, transmission service providers and system operators could create a significant burden on the planning and operation of an inverter-based generation dominated power system.

In recent years, the concept of grid-forming inverter-based resources was proactively pursued by the research community. A grid-forming resource does not require a certain system strength to be interconnected to a power system, and can precisely control its output voltage amplitude and frequency to create a strong voltage source itself. This innovation has great potential to improve the performance of inverter-based generation and, according to some studies, can make 100% inverter-based operations feasible. Although various research entities have put great effort into studying the 100% renewable scenario and identified requirements to achieve this ambitious goal, it must be recognized that power systems will not become 100% renewable overnight. If grid-forming technologies are to be a viable solution, they will have to operate reliably in parallel with synchronous generation during the extended transition period. Furthermore, not all of the necessary adjustments and new technologies can be easily implemented to reach a 100% renewable scenario. Meanwhile, since electricity is a critical aspect of people's lives, there will still be extremely high standards for power system reliability regardless of whether electricity is produced by traditional synchronous machines or by inverter-based renewable generation.

To the best of the authors' knowledge, there is no practical example of parallel grid-forming inverters in a large power system under various penetration levels of inverter-based generation. There also is currently no commercially-available grid-forming inverter product for a large-scale power system application. This could be due to a lack of collaboration between the research community, manufacturers and system operators resulting in two intertwined issues: (1) without clear technical specifications of what grid-forming capabilities should entail, manufacturers have no clear path or incentive to develop this capability; (2) at the same time, without commercially-available products or prospects for such products, system operators cannot require these capabilities or introduce markets for these products. Thus, we continue planning and operating the system with the tools that are currently available.

It is critical to have a road map to get from present levels of inverter-based generation toward a reliable inverter-based generation dominated power system in the future. It will require collaboration among manufacturers, system operators and research organizations from a holistic perspective to reach consensus and develop a road map that would (1) encourage research entities to continue to identify the improvement and innovation of existing and new technologies, (2) provide incentives to manufacturers for product development and commercial application, and (3) assist system operators with more options and suggestions to continue to maintain and operate the power system in a reliable and cost-effective manner.

Given the growth of inverter-based resources globally, the industry needs to quickly figure out how to make this transition from concept to feasibility to commercial availability for implementation. The longer we wait, the more difficult it will become, since existing inverter-based resources will be difficult or not feasible to retrofit. Some of these collaborations have already started. For example, the European Commission-funded project called the Massive Integration of Power Electronic Devices (MIGRATE (https://www.h2020-migrate.eu/)) has brought together European transmission system operators, universities and manufacturers in an EU-funded project to address challenges with extremely high penetration of inverter-based generation. ENTSO-E (European Network of Transmission System Operators for Electricity) also established a technical group in 2016 on High Penetration (TG HP) and developed an Implementation Guidance Document on High Penetration of Power Electronic Interfaced Power Sources (HPoPEIPS (https://docstore.entsoe.eu/Documents/Network%20codes%20documents/Implementation/ Similarly, a new task force will start within the Reliability Working Group at ESIG to aim for the same goal, with the expectation to build a consensus and develop a road map of how to get from where we are today to an inverter-based resources dominated system, while operating the system in a reliable and stable manner.

Julia Matevosyan
Lead Planning Engineer, Resource Adequacy
ERCOT

Shun-Hsien (Fred) Huang
Manager of Regional Planning,Transmission Planning
ERCOT

Comments

1. Peter Boerre Eriksen, Consulting says

January 14, 2019 at 1:56 pm (https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/#comment-1406)

You describe an important topic which will be more and more critical in many power systems in the years to come.
It is a good an obvious idea with a road map. This could help coordinating the efforts and solutions between researchers, manufactors and system operators.

Reply

2. Peter Boerre Eriksen, Consultant, Denmark says

   January 14, 2019 at 2:00 pm (https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/#comment-1407)

   A good proposal for initiating the important coordination and cooperation between Research, Manufactor and System operator.

   Reply

   - Julia Matevosyan says

     January 17, 2019 at 3:00 pm (https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/#comment-1413)

     Thank you, Peter!

     Reply

3. Zibbi Styczynski says

   January 17, 2019 at 2:21 pm (https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/#comment-1412)

This is the next big and important step towards a new power system. Up to now Many myths concerning RES participation in the power system have been broken: power system is still stable and still not only the serious discussion follow the developments. The best argument is still a practical demonstration so I agree with Peter and I welcome also very well the proposed next steps...

Reply

4. Kerinia Cusick says

January 22, 2019 at 4:46 pm (https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/#comment-1419)

Are all "smart" inverters also "grid-forming" inverters? By smart, I mean inverters that comply with IEEE 1547-2018. I realize IEEE 1547 only applies to distribution connected, but suspect there is a similar standard for transmission connected.

Reply

5. Ric O'Connell (http://gridlab.org) says

January 28, 2019 at 5:05 pm (https://www.esig.energy/necessity-of-a-road-map-toward-a-reliable-inverter-based-generation-dominated-power-system/#comment-1426)

Hi Kerinia:

"Smart" inverters that comply with IEEE 1547-2018 are NOT grid forming, they are simply implementing protocols that provide for voltage regulation and frequency and voltage ride through. They still are current source inverters and inject current behind a voltage – in other words, they need a stable voltage to operate. Grid forming inverters provide a voltage source.

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Hawaiian Electric

Oahu Programs at a Glance

Wondering what program may be right for you? It really depends on your individual situation and your short- and long-term goals. If you're trying to decide between available programs for private rooftop solar or other renewables, here are a few questions to help determine the best fit.

How do you currently use energy? How might that change in the future? What do you want to achieve through participating in one of our programs? Here's a quick comparison of the available programs.

This chart provides an example of a hypothetical total bill for each available program using the same amount of energy delivered and received. As with all examples, your result will vary depending your energy use. Please review the details for each program for additional information that will help you determine the program that's right for you.

OAHU	CGS	CGS Plus	CSS	Smart Export
Export Allowed	Yes	Yes	No	Yes
Export Restrictions	No	No	N/A	Solar Day
Reconciliation	Monthly	Annual	N/A	Annual
Minimum Bill	$25	$25	$25	$25
Credit rate (c/kWh)***	$0.15	$0.10	N/A	$0.15
Program Cap	51.3 MW	35 MW	N/A	25 MW
Inverter Requirements	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.*	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.
Controls	N/A	Yes: Utility or Aggregator	Customer	Yes: Economic
Communications	N/A	N/A	Yes	N/A
Hypothetical Bill Comparison:**	$93.28	$118.38	$169.09	$93.79

**Prior to 3/10/2018 CGS Customers were required to program their advanced inverters to include TROV-2, Full ride-through and Fixed Power Factor. They must now be re-programmed to current requirements as noted in Rule 14H.*

***Assumes a residential bill with Delivered (DEL) energy of 503 kWh, Received (REC) energy of 907 kWh, with a NET of 404 kWh and the application of the monthly bill credit for Oahu. Does not reflect any benefit from accrued credits. Calculation is based on rates effective October 2018. Some rates vary monthly. Non-residential customers subject to different rate schedules and higher minimum bill.*

****Credit rate shown is rounded to the nearest whole value. Standard retail rates applied for energy delivered/used when rooftop solar or other renewable system is not in use or exporting to the grid. Customers on rates other than retail should contact us to verify whether those options will apply in coordination with these programs.*

Customer Grid-Supply remains open until installed capacity is reached. New applications are placed into queue for processing when space in the program becomes available. There is no guarantee that space will become available. New applications may be submitted via mail and are not supported in the Customer Interconnection Tool.

NEM and NEM Plus are not shown in this table. The NEM program is closed and NEM Plus is only available to customers already enrolled in the NEM program.

Hypothetical Oahu Bill and Credit Calculations

This chart shows how we calculated the hypothetical total bill for each program. Here are the key items to note:

- We used the same net kilowatt hour usage to demonstrate the impact ofeach rate.
- The dollar amount shown is derived from multiplying the usage by the rate in effect in October 2018. Just like usage, some rates adjust monthly too. So, please keep that in mind while studying this example.
- The credit calculation is an important difference with the program. Please refer to the charts below to see how those credits are determined.

Oahu	NET kWH	CGS Total	CGS Plus Total	CSS total	Smart Export Total
Customer Charge	Flat	11.5	11.5	11.5	11.5
Base Fuel Energy	404	51.45	51.45	51.45	51.45
Non Fuel Energy	404	55.49	55.49	55.49	55.49
Energy Cost Adjustment	404	20.16	20.16	20.16	20.16
IRP Cost Recovery	404	-0.03	-0.03	-0.03	-0.03
PBF Surcharge	404	2.34	2.34	2.34	2.34
Purchased Power Adjustment	404	21.76	21.76	21.76	21.76
RBA Rate Adjustment	404	5.21	5.21	5.21	5.21
Grid Supply Credit	404	-75.81	-50.71	N/A	-75.3
Green Infrastructure Fee	404	1.21	1.21	1.21	1.21
Total		93.28	118.38	169.09	93.79

The next two charts provide a look at how the bill credit is calculated. As with the previous example, we've kept the amount of delivered, received and net kilowatt hours the same for comparison purposes. However, we've demonstrated how the banked credit is applied by reversing the amount of delivered and received energy. Here are the key items to note:

- Credits are earned for each kilowatt hour you delivered to the grid each month multiplied by the rate for your chosen program.
- Smart Export and CGS Plus allow you to accrue and use credits over aone-year period. So, if the utility receives more energy from you than it delivers – you'll be able to bank unused credits to use in other months when the situation is reversed.
- Each year, remaining credits in your bank will be applied to any eligible kilowatts that haven't yet been credited during the previous 12 months. Credits that remain after the true-up are surrendered.
- Appropriately sizing your system is the most important consideration. Ideally,you want to have earned enough credits to offset each kilowatt hour of energy delivered to you throughout the year and end up (after the annual true-up) with very few, if any, banked credits remaining. However, make sure to consider future energy use plans such as home improvements (i.e. split A/C) or the purchase of electric vehicles when determining your overall system size.

Hawaiian Electric

Oahu: When energy delivered to customer exceeds energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.1507	907	503	404	$75.80	N/A
CGS Plus	0.1008	907	503	404	$50.70	0
CSS	N/A	907	503	404	N/A	N/A
Smart Export	0.1497	907	503	404	$75.30	0

Oahu: When energy delivered to customer is less than energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.1507	503	907	404	$75.80	N/A
CGS Plus	0.1008	503	907	404	$50.70	$ 40.72
CSS	N/A	503	907	404	N/A	N/A
Smart Export	0.1497	503	907	404	$75.30	$ 60.48

Hawaiian Electric

Hawaii Island Programs at a Glance

Wondering what program may be right for you? It really depends on your individual situation and your short- and long-term goals. If you're trying to decide between available programs for private rooftop solar or other renewables, here are a few questions to help determine the best fit.

How do you currently use energy? How might that change in the future? What do you want to achieve through participating in one of our programs? Here's a quick comparison of the available programs.

This chart provides an example of a hypothetical total bill for each available program using the same amount of energy delivered and received. As with all examples, your result will vary depending your energy use. Please review the details for each program for additional information that will help you determine the program that's right for you.

HAWAII ISLAND	CGS	CGS Plus	CSS	Smart Export
Export Allowed	Yes	Yes	No	Yes
Export Restrictions	No	No	N/A	Solar Day
Reconciliation	Monthly	Annual	N/A	Annual
Minimum Bill	$25	$25	$25	$25
Credit rate (c/kWh)* **	$0.15	$0.10	N/A	$0.11
Program Cap	9.91 MW	12 MW	N/A	10 MW
Inverter Requirements	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.*	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.
Controls	N/A	Yes: Utility or Aggregator	Customer	Yes: Economic
Communications	N/A	N/A	Yes	N/A
Hypothetical Bill Comparison:**	$119.20	$142.29	$195.36	$140.03

**Prior to 3/10/2018 CGS Customers were required to program their advanced inverters to include TROV-2, Full ride-through and Fixed Power Factor. They must now be re-programmed to current requirements as noted in Rule 14H.*

***Assumes a residential bill with Delivered (DEL) energy of 503 kWh, Received (REC) energy of 907 kWh, with a NET of 404 kWh and the application of the monthly bill credit for Hawaii Island. Does not reflect any benefit from accrued credits. Calculation is based on rates effective October 2018. Some rates vary monthly. Non-residential customers subject to different rate schedules and higher minimum bill.*

****Credit rate shown is rounded to the nearest whole value. Standard retail rates applied for energy delivered/used when rooftop solar or other renewable system is not in use or exporting to the grid. Customers on rates other than retail should contact us to verify whether those options will apply in coordination with these programs.*

Customer Grid-Supply remains open until installed capacity is reached. New applications are placed into queue for processing when space in the program becomes available. There is no guarantee that space will become available. New applications may be submitted via mail and are not supported in the Customer Interconnection Tool.

NEM and NEM Plus are not shown in this table. The NEM program is closed and NEM Plus is only available to customers already enrolled in the NEM program.

Hypothetical Hawaii Island Bill and Credit Calculations

This chart shows how we calculated the hypothetical total bill for each program. Here are the key items to note:

- We used the same net kilowatt hour usage to demonstrate the impact of each rate.
- The dollar amount shown is derived from multiplying the usage by the rate in effect in October 2018. Just like usage, some rates adjust monthly too. So, please keep that in mind while studying this example.
- The credit calculation is an important difference with the program. Please refer to the charts below to see how those credits are determined.

Hawaii Island	NET kWH	CGS Total	CGS Plus Total	CSS total	Smart Export Total
Customer Charge	Flat	11.5	11.5	11.5	11.5
Base Fuel Energy	404	51.53	51.53	51.53	51.53
Non Fuel Energy	404	72.34	72.34	72.34	72.34
Energy Cost Adjustment	404	42.05	42.05	42.05	42.05
PBF Surcharge	404	2.34	2.34	2.34	2.34
Purchased Power Adjustment	404	9.36	9.36	9.36	9.36
RBA Rate Adjustment	404	5.03	5.03	5.03	5.03
Grid Supply Credit	404	-76.16	-53.07	N/A	-55.33
Green Infrastructure Fee	404	1.21	1.21	1.21	1.21
Total		119.2	142.29	195.36	140.03

The next two charts provide a look at how the bill credit is calculated. As with the previous example, we've kept the amount of delivered, received and net kilowatt hours the same for comparison purposes. However, we've demonstrated how the banked credit is applied by reversing the amount of delivered and received energy. Here are the key items to note:

- Credits are earned for each kilowatt hour you delivered to the grid each month multiplied by the rate for your chosen program.
- Smart Export and CGS Plus allow you to accrue and use credits over a one-year period. So, if the utility receives more energy from you than it delivers – you'll be able to bank unused credits to use in other months when the situation is reversed.
- Each year, remaining credits in your bank will be applied to any eligible kilowatts that haven't yet been credited during the previous 12 months. Credits that remain after the true-up are surrendered.
- Appropriately sizing your system is the most important consideration. Ideally, you want to have earned enough credits to offset each kilowatt hour of energy delivered to you throughout the year and end up (after the annual true-up) with very few, if any, banked credits remaining. However, make sure to consider future energy use plans such as home improvements (i.e. split A/C) or the purchase of electric vehicles when determining your overall system size.

Hawaiian Electric

Hawaii Island: When energy delivered to customer exceeds energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.1514	907	503	404	$ 76.15	N/A
CGS Plus	0.1055	907	503	404	$ 53.07	0
CSS	N/A	907	503	404	N/A	N/A
Smart Export	0.11	907	503	404	$ 55.33	0

Hawaii Island: When energy delivered to customer is less than energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.1514	503	907	404	$ 76.15	N/A
CGS Plus	0.1055	503	907	404	$ 53.07	$ 42.62
CSS	N/A	503	907	404	N/A	N/A
Smart Export	0.11	503	907	404	$ 55.33	$ 44.44

Hawaiian Electric

Maui County Programs at a Glance

Wondering what program may be right for you? It really depends on your individual situation and your short- and long-term goals. If you're trying to decide between available programs for private rooftop solar or other renewables, here are a few questions to help determine the best fit.

How do you currently use energy? How might that change in the future? What do you want to achieve through participating in one of our programs? Here's a quick comparison of the available programs.

This chart provides an example of a hypothetical total bill for each available program using the same amount of energy delivered and received. As with all examples, your result will vary depending your energy use. Please review the details for each program for additional information that will help you determine the program that's right for you.

MAUI COUNTY	CGS	CGS Plus	CSS	Smart Export
Export Allowed	Yes	Yes	No	Yes
Export Restrictions	No	No	N/A	Solar Day
Reconciliation	Monthly	Annual	N/A	Annual
Minimum Bill	$25	$25	$25	$25
Credit rate (c/kWh)***	Lanai: $0.28 Maui: $0.17 Molokai: $0.24	Lanai: $0.21 Maui: $0.12 Molokai: $0.17	N/A	Lanai: $0.21 Maui: $0.14 Molokai: $0.17
Program Cap†	14.12 MW	7 MW	N/A	5 MW
Inverter Requirements	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.*	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.	Advanced with Volt Var and Frequency Watt activated; Fixed Power Factor deactivated.
Controls	N/A	Yes: Utility or Aggregator	Customer	Yes: Economic
Communications	N/A	N/A	Yes	N/A
Hypothetical Bill Comparison:**	Lanai: $70.07 Maui: $89.62 Molokai: $82.61	Lanai: $105.68 Maui: $114.72 Molokai: $119.13	Lanai: $210.30 Maui: $175.94 Molokai: $203.68	Lanai: $105.73 Maui: $103.46 Molokai: $119.99

**Prior to 3/10/2018 CGS Customers were required to program their advanced inverters to include TROV-2, Full ride-through and Fixed Power Factor. They must now be re-programmed to current requirements as noted in Rule 14H.*

***Assumes a residential bill with Delivered (DEL) energy of 503 kWh, Received (REC) energy of 907 kWh, with a NET of 404 kWh and the application of the monthly bill credit for each island. Does not reflect any benefit from accrued credits. Calculation is based on rates effective October 2018. Some rates vary monthly. Non-residential customers subject to different rate schedules and higher minimum bill.*

****Credit rate shown is rounded to the nearest whole value. Standard retail rates applied for energy delivered/used when rooftop solar or other renewable system is not in use or exporting to the grid. Customers on rates other than retail should contact us to verify whether those options will apply in coordination with these programs.*

†Program cap applies to Maui County in total.

Hawaiian Electric

Customer Grid-Supply remains open until installed capacity is reached. New applications are placed into queue for processing when space in the program becomes available. There is no guarantee that space will become available. New applications may be submitted via mail and are not supported in the Customer Interconnection Tool.

NEM and NEM Plus are not shown in this table. The NEM program is closed and NEM Plus is only available to customers already enrolled in the NEM program.

Hypothetical Maui County Bill and Credit Calculations

This chart shows how we calculated the hypothetical total bill for each program by island. Here are the key items to note:

- We used the same net kilowatt hour usage to demonstrate the impact ofeach rate.
- The dollar amount shown is derived from multiplying the usage by the rate in effect in October 2018. Just like usage, some rates adjust monthly too. So, please keep that in mind while studying this example.
- The credit calculation is an important difference with the program. Please refer to the charts below to see how those credits are determined.

Maui	NET kWH	CGS Total	CGS Plus Total	CSS total	Smart Export Total
Customer Charge	Flat	8.5	8.5	8.5	8.5
Base Fuel Energy	404	115.7	115.7	115.7	115.7
Non Fuel Energy	404	50.44	50.44	50.44	50.44
Energy Cost Adjustment	404	-16.51	-16.51	-16.51	-16.51
PBF Surcharge	404	2.34	2.34	2.34	2.34
Purchased Power Adjustment	404	-0.3	-0.3	-0.3	-0.3
RBA Rate Adjustment	404	1.6	1.6	1.6	1.6
Interim Increase 2018	404	12.96	12.96	12.96	12.96
Grid Supply Credit	404	-86.32	-61.22	N/A	-72.48
Green Infrastructure Fee	404	1.21	1.21	1.21	1.21
Total		89.62	114.72	175.94	103.46

Molokai	NET kWH	CGS Total	CGS Plus Total	CSS total	Smart Export Total
Customer Charge	Flat	8.5	8.5	8.5	8.5
Base Fuel Energy	404	132.52	132.52	132.52	132.52
Non Fuel Energy	404	64.19	64.19	64.19	64.19
Energy Cost Adjustment	404	-20.39	-20.39	-20.39	-20.39
PBF Surcharge	404	2.34	2.34	2.34	2.34
RBA Rate Adjustment	404	1.6	1.6	1.6	1.6
Interim Increase 2018	404	13.71	13.71	13.71	13.71
Grid Supply Credit	404	-121.07	-84.35	N/A	-83.69
Green Infrastructure Fee	404	1.21	1.21	1.21	1.21
total		82.61	119.33	203.68	119.99

Lanai	NET kWH	CGS Total	CGS Plus Total	CSS total	Smart Export Total
Customer Charge	Flat	8.5	8.5	8.5	8.5
Base Fuel Energy	404	162.3	162.3	162.3	162.3
Non Fuel Energy	404	52.22	52.22	52.22	52.22
Energy Cost Adjustment	404	-32.05	-32.05	-32.05	-32.05
PBF Surcharge	404	2.34	2.34	2.34	2.34
RBA Rate Adjustment	404	1.6	1.6	1.6	1.6
Interim Increase 2017	404	14.18	14.18	14.18	14.18
Grid Supply Credit	404	-140.23	-104.62	N/A	-104.57
Green Infrastructure Fee	404	1.21	1.21	1.21	1.21
Total		70.07	105.68	210.3	105.73

The following charts provide a look at how the bill credit is calculated by island. As with the previous example, we've kept the amount of delivered, received and net kilowatt hours the same for comparison purposes. However, we've demonstrated how the banked credit is applied by reversing the amount of delivered and received energy. Here are the key items to note:

- Credits are earned for each kilowatt hour you delivered to the grid each month multiplied by the rate for your chosen program.
- Smart Export and CGS Plus allow you to accrue and use credits over aone-year period. So, if the utility receives more energy from you than it delivers – you'll be able to bank unused credits to use in other months when the situation is reversed.
- Each year, remaining credits in your bank will be applied to any eligible kilowatts that haven't yet been credited during the previous 12 months. Credits that remain after the true-up are surrendered.
- Appropriately sizing your system is the most important consideration. Ideally, you want to have earned enough credits to offset each kilowatt hour of energy delivered to you throughout the year and end up (after the annual true-up) with very few, if any, banked credits remaining. However, make sure to consider future energy use plans such as home improvements (i.e. split A/C) or the purchase of electric vehicles when determining your overall system size.

Maui: When energy delivered to customer exceeds energy received from customer.

Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.1716	907	503	404	$ 86.31	N/A
CGS Plus	0.1217	907	503	404	$ 61.22	0
CSS	N/A	907	503	404	N/A	N/A
Smart Export	0.1441	907	503	404	$ 72.48	0

Maui: When energy delivered to customer is less than energy received from customer.

Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.1716	503	907	404	$ 86.31	N/A
CGS Plus	0.1217	503	907	404	$ 61.22	$ 49.17
CSS	N/A	503	907	404	N/A	N/A
Smart Export	0.1441	503	907	404	$ 72.48	$ 58.22

Hawaiian Electric

Molokai: When energy delivered to customer exceeds energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.2407	907	503	404	$ 121.07	N/A
CGS Plus	0.1677	907	503	404	$ 84.35	0
CSS	N/A	907	503	404	N/A	N/A
Smart Export	0.1664	907	503	404	$ 83.70	0

Molokai: When energy delivered to customer is less than energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.2407	503	907	404	$ 121.07	N/A
CGS Plus	0.1677	503	907	404	$ 84.35	$ 67.75
CSS	N/A	503	907	404	N/A	N/A
Smart Export	0.1664	503	907	404	$ 83.70	$ 67.23

Lanai: When energy delivered to customer exceeds energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.2788	907	503	404	$ 140.24	N/A
CGS Plus	0.208	907	503	404	$ 104.62	0
CSS	N/A	907	503	404	N/A	N/A
Smart Export	0.2079	907	503	404	$ 104.57	0

Lanai: When energy delivered to customer is less than energy received from customer.						
Program	Rate/kWh	DEL	REC	NET	Monthly Total	Banked Credit
CGS	0.2788	503	907	404	$ 140.24	N/A
CGS Plus	0.208	503	907	404	$ 104.62	$ 84.03
CSS	N/A	503	907	404	N/A	N/A
Smart Export	0.2079	503	907	404	$ 104.57	$ 83.99

Transmission System

John J. Cruz Jr., PE
AGMETS

Agenda

- Introduction
- Renewable Integration Study
- System Impact of New Power Plant
- Grid Controller
- BESS Negotiations

Introduction

- GPA has performed the following studies that form the bulk of transmission system analysis and capital planning
  - 2010 Long Range Transmission Study
  - Energy Storage Technical and Economic Feasibility Study
  - Renewable Energy Project System Impact Studies (Phase I & II)
  - Renewable Integration Study/System Improvement Study (2018)
  - Analytical Investigations in support of the Phase I Energy Storage Projects at Agana and Talofofo
  - System Impact Study for New Power Plant
- System Impact Studies investigate:
  - How the new generation asset will affect the grid
  - Determine how to mitigate these problems
  - Determine how these new systems can improve grid resiliency

Renewable Integration Study/System Improvement Study Results

- Study Goal: The study's goal was to determine the ultimate penetration level of the GPA system from a technical perspective, such that economic feasibility and not technical limits determine the penetration limits for the electrical grid.

Renewable Integration Study/System Improvement Study Results

- The current generation system does not support high penetration of intermittent renewable energy
  - Very limited ability to accept PV energy without severe degradation of the reliability of the transmission system.
  - Main limitations due to the characteristics of existing thermal generation including:
    - Limited ability to support the grid during large ramp up/down events
    - Meeting the system peak following sunset
    - Inability to cycle on a daily basis
    - Very limited response capability
    - Relatively high minimum generation levels.

Caveats

- Conclusion of IEEE Journal of Photovoltaics (October 2013) paper:
  - *Changes in the Economic Value of Photovoltaic Generation at High Penetration Levels: A Pilot Case Study of California*
  - By Andrew D. Mills and Ryan H. Wiser
- **Without any mitigation strategies to stem the decline in the value of PV, however, the value of PV drops considerably with increasing penetration.**
- GPA's planning efforts seek to determine the mitigation strategies necessary to prevent this decline in value

Renewable Integration Study/System Improvement Study Results

- Due primarily to these limitations, the penetration limit of the current system is below the capacity of the planned Phase I and Phase II Renewable Energy PV projects and Net Metering growth.
- Without recommended system improvements, the Phase II projects may require significant curtailment, particularly during the early morning hours of high PV levels and lower system loads.
- With system improvements, the penetration limit of the GPA system is only constrained by the economic feasibility of the improvements and the energy savings achieved through the use of PV energy.
  - Following through with the Study recommendations removes technical limitations to increasing renewable penetration
  - Only economics will limit the amount of renewable energy we can place on the GPA grid

Renewable Integration Study/System Improvement Study Results

- With the recommended system improvements, the renewable energy penetration limit of the GPA transmission system is only constrained by the economic feasibility of the improvements and the energy savings achieved through the use of PV energy.
- This is from the perspective of the transmission grid. GPA is looking at the limitations and mitigation strategies relevant to the distribution system.

Renewable Integration Study/System Improvement Study Results

- Without sufficient Synchronous Generation or Synchronous Condensers operating, inverter-based generation will fail.
- Grid-Tied inverters need to synchronize to the grid voltage and frequency. Otherwise they will not work and not provide power from solar PV arrays.
  - Kaua'i Island Utility Cooperative (KIUC) runs synchronous condensers when solar PV supplies 100% of energy to its grid
  - KIUC ended its net metering program in 2008.
- Inverter-based generation cannot supply short-circuit current as well as synchronous generators or condensers. You need sufficient short-circuit current in order for system protection to work. Otherwise the system will blackout during system faults.

Problems Associated with Increasing Penetration of NEM

- Many islanded systems have observed that the UFLS system becomes less effective during periods of high distributed generation. This occurs because the DG will decrease the net load on each substation feeder. This in turn decreases the total load in each stage of UFLS that can be tripped.
- For the GPA system, if the proposed levels of ESS through Phase III are configured to provide grid frequency support, the risk of insufficient UFLS load shedding becomes less. However, it is recommended that GPA continue to observe the net feeder loading and installed DG/PV to assess the impact of DG on UFLS stages. If the actual capacity of DG/PV significantly exceeds the forecasted DG/PV estimates, the impact on UFLS will become more significant.
- GPA has observed this problem with increasing UFLS outages with smaller increases in NEM.

BESS Results

- Battery Energy Storage Systems
  - Using large utility-scale Battery Energy Storage Systems (BESS) has a game-changing potential to reduce Underfrequency Load Shedding (UFLS), and significantly improve system stability and regulate system frequency.
  - Proof is in the pudding – We are observing this potential with the newly installed systems at Agana and Talofofo
  - Each utility-scale BESS addition further improves system resiliency
  - Costs dropping but still a significant investment
- BESS System Additions to Target Problems
  - Eliminate Duck Curve and eliminate issues now experienced with over 25% of daytime loads provided by solar PV. Within three years, daytime renewable energy will provide up to 50% of daytime peak load. May be economic to store a portion of this energy for use at night.
  - Replace peaking units at night and reduce energy production costs.
  - Provide droop response to supplement Agana ESS

ESS Ramping and Regulation

- The proposed Phase II ESS's are assumed to be available for conversion into grid support functionality. The Agana and Talofofo ESS's are also expected to be available for grid support. The Phase III renewable projects are also expected to include load shifting capable ESS's, with grid support services.
- With all these ESS's available for grid support, and operating on a droop characteristic, large frequency variations will be mitigated.
- What remains will be smaller frequency variations that could occur due to variations in net load, primarily driven by variations due to the intermittency of renewable generation sources.
  - The variation in net load will require that the online generation ramp up and down to compensate and balance load and generation, or that some other sources contribute to the ramping.
  - The optimal solution is to use some of the capacity across the whole fleet of ESS's to contribute to the ramping.
  - This is most effectively accomplished via automatic generation control (AGC). AGC is one of the functions of the **Grid Controller** GPA will be procuring.

Excess Energy Estimation and Mitigation

- The GPA grid will not be able to accept more solar PV during low load + high PV production periods. Additions of intermittent PV generation without energy-shifting storage will cause serious grid issues if not mitigated.
- A minimum amount of synchronous generation needs to be online to provide adequate system strength, measured in terms of short circuit MVA (SC MVA), and to provide spinning reserves and regulation capabilities.
- Inverter-based technologies such as PV grid-tied inverters or ESS inverters need adequate system strength or SC MVA in order to operate safely and reliably. Otherwise, they will stop working.

115 KV Improvements Recommendations

- 115 KV Transmission System
  - Add new Talofofo to Agana 115 KV line to better and more efficiently export significant power from new utility-scale renewable energy systems
  - Solve issues arising from trip of Hanwha Apra to Piti 115 KV line during the day
  - Require 115 KV interconnection for new utility-scale systems
  - Retire the two Cabras-Agana 115 KV lines and their costly maintenance expense.
  - Loop the 115 KV system to improve system resiliency

Main Take Away

- Beyond the Phase II PV projects, any additional PV energy may be required to curtail during high PV production hours or stored in ESS's and scheduled to the grid during night-time or lower PV production times.
- So long as the PV beyond Phase II includes ESS's for load shifting and grid support, the GPA system is limited only by the economic costs of load shifting the PV energy compared to the cost of obtaining the energy from other production methods.
- Unless GPA completes the execution of the Renewable Integration Study, there is no renewable energy future

PV Penetration Levels and Required Improvements

Phase I - 25 MW PV
Automatic Generation Control/Grid Controller
Phase II - 120 MW PV
115 kV Relay Upgrades
34.5 kV Relay Upgrades
Flexible Generation Plant
Malojloj - Agana 115 kV Transmission Line
ESS Transient Grid Support
Phase III - 40 MW PV
Transient Grid Support from Hanwha & KEPCO/LG
Synchronous Condenser at Flexible Generation Plant
Temes/Yigo/Macheche Synchronous Condenser Upgrades
Load Shifting/Grid Support ESS
Phase IV & Beyond
Load-shifting/Grid Support ESS

RIS New Project Recommendations

System Improvement	Risk if not built
Automatic Generation Control	Uneconomical use of PV energy, large curtailments of PV, poor reliability, poor frequency control, poor transient recovery response
115 kV line clearing time, 5 cycles from both ends	Long clearing times create large frequency dips during line faults, result in excessive load shedding, puts system at risk for cascading outage and collapse, does not meet transmission planning reliability criteria
34.5 kV line clearing time, 6 cycles from both ends	Long clearing times create large frequency dips for line faults, result in excessive load shedding, does not meet GPA transmission planning criteria
Transient Grid Support from ESS's at Agana, Talofofo, Orote, South Finegayan	Without ESS transient support, excessive load shedding occurs, FIDVR effects are worse, does not meet GPA transmission planning criteria, cannot accept large amounts of renewable generation at peak solar production conditions
Transient Grid Support from ESS's at Hanwha, KEPCO/LG	Without additional ESS support, load shedding occurs for FIDVR events, alternately other units would need to be online creating renewable generation curtailments
Flexible Generation Plant	Without flexible units that can be decommitted, renewable generation would be forced to curtail during peak production times, less renewable energy would be used each day
Flexible Generation Synchronous Condenser	Without SC option, the inverter based sources would be at risk for inverter cessation during disturbances, resulting in more load shedding, and risk of inverters not resetting after a disturbance, leading to system collapse
TEMES/Yigo/Macheche Synchronous Condenser	Without SC in southwest part of the system, the system remains at risk for inverter cessation during a disturbance, especially near Harmon, with more load shedding and possible system collapse
Malojloj - Agana 115 kV Line Addition	Without this addition, the single outage of the Piti-Agana 115 kV line caused a large loss of generation, load shedding, and does not meet the transmission planning criteria
TEMES/Yigo/Macheche Remote Start/Stop	Energy shortage to serve GPA load following severe system contingencies and ESS contingencies

Other New Project Recommendations

- Advanced Adaptive Underfrequency Load Shedding Protection
- Grid Controller System
  - Has Automatic Generation Control (AGC) Function
  - Expanded Functional Requirements to optimize System Stability, reduce operating costs, improve power quality, significantly reduce outages, and reduce future investment costs.

Operational and Design Recommendations for New Power Plant

- The Ukudu Power Plant will include a 25 MW/15 MWH Battery Energy Storage System (BESS)
- This BESS should be configured under automatic relay control to inject power immediately upon the trip of any Ukudu unit.
- The New KEPCO Diesel Plant should be placed on remote start and under relay control to begin start-up upon the trip of any Ukudu unit.

Grid Controller General Functional Requirements

- Autonomous power system grid controller must provide:
  - Automatic Generation Control and Resource Commitment system of existing and future fossil fuel-fired generation, renewable energy generation, energy storage, and demand response resources;
  - Security Constrained Economic Dispatch of existing and future resources including but not limited to:
    - Fossil Fuel-Fired Generation
    - Energy-Shifting Storage
    - Battery Energy Storage Systems
    - Variable Renewable Energy Generation (Curtailment)
    - Firm Renewable Energy Generation
    - Demand Response Resources/Interruptible Loads
    - Electric Vehicle V2G Charging Systems
    - Synchronous Condensers
    - Short Circuit Current Ratio Constraints
  - Optimal Control of Battery Energy Storage System (BESS) Charging (Economic and Stability Objective Function);
  - Optimize BESS operation in contingency (spinning reserve) mode with remote start generation;
  - Solar PV curtailment
  - Optimal Control of Battery Energy Storage System (BESS) Charging (Economic and Stability Objective Function);
  - Dispatch of Demand Response Resources.
  - Optimize charging of electric vehicles to reduce need for future capacity investments.
- System must optimize grid operations for system stability, reliability, and cost

BESS Negotiations

- Because of the ability for BESS to fix long-standing grid problems and new problems created by intermittent renewable generation, GPA is negotiating with current projects with BESS for additional battery energy capacity.

Questions?

Report Summary Observations

- Almost an average of 3 power outages per day in 2019
- 67% of the outages were classified as Under Frequency Load Shedding (UFLS) events
- Generation resources were 91% of the total UFLS events
- NRG Solar totaled 149 events or 23% of the total UFLS generation outages
- NRG Solar had the highest count by generation type of UFLS outages in 2019
- NRG Solar UFLS outages increase in frequency (of solar production) at the beginning of the day, mid-day and at the end of the day (hours ending 9, 11, 13 and 16) – When solar production is:
    - Ramping up for the day
    - At max daily production
    - Ramping down for the day
- NRG Solar has the highest number of outages in March when solar is at the peak monthly production for the year
- Preliminary (existing Net Metering) data suggests that UFLS events increase with:
    - Large single solar array installed on feeder (big install)
    - Large total solar KW installed on feeder from multiple installs (many small installs)
    - Feeder has high solar installations in relation to feeder maximum demand
    - Feeder has high solar installations in relation to feeder minimum daytime demand

This report is a summary of the Guam Power Authority's (GPA) **power outages**. The data in this study was supplied by GPA. The data was provided from the "qOutageLog_Base" file. This database is used by GPA to track system outages. A subset of the database was used to look specifically at the under frequency events. The analysis was conducted using the then most recent, entire calendar year of 2019. The summary of this data was prepared by Utility Financial Solutions, LLC (UFS).

> https://www.nerc.com/
> "The purpose of Under Frequency Load Shedding (UFLS) is to balance generation and load when an event causes a significant drop in frequency of an interconnection or islanded area."

You can see from the Table 1 below that there was a total of 1,087 outages in 2019 **(almost an average of 3 power outages per day)**. The outages are generically classified as either Under Frequency Load Shedding (UFLS) events and non UFLS events. You will notice that **67% of the outages were classified as UFLS**.

Table 1 - UFLS vs. Non UFLS Events

Years: 2019

UFLS	RootLevelName	UFLSInstigatorName	Count of UFLS	Count of UFLS2
⊞	FALSE		358	33%
⊞	TRUE		729	67%
	Grand Total		**1,087**	**100%**

Table 2 shows of the UFLS events in 2019 you can see that **generation resources were 91% of the total outages.** Distribution accounted for 2% while Transmission tallied 8% of the UFLS events.

Table 2 – UFLS by Root Level Type

Years	2019
UFLS	TRUE

RootLevelName	UFLSInstigatorName	Count of UFLS	Count of UFLS2
Distribution		11	2%
Generation		662	91%
Transmission		56	8%
Grand Total		**729**	**100%**

Table 3 shows of the UFLS generation events, **NRG Solar totaled 149 events or 23% of the total generation outages.**

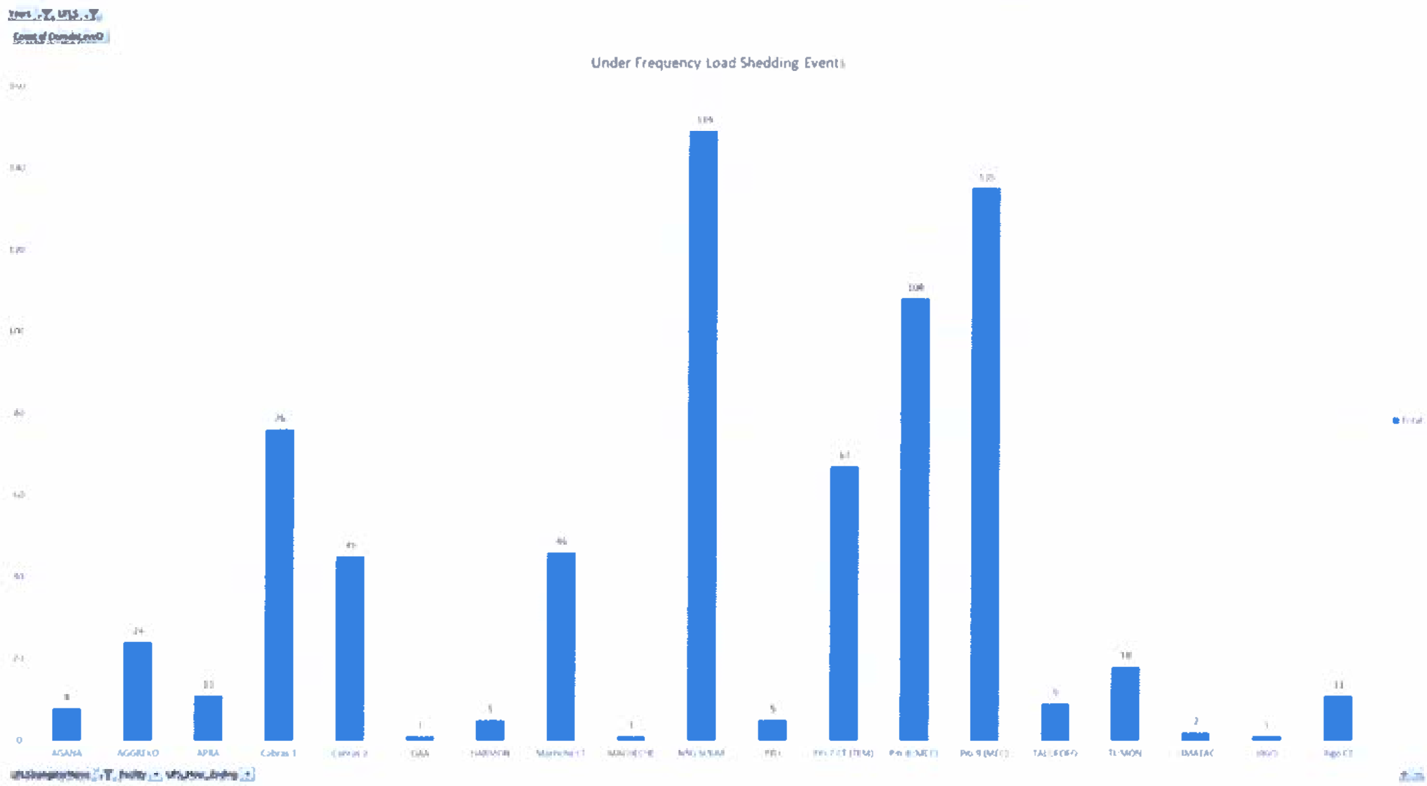
Table 3 – UFLS for Generation

Years	2019
UFLS	TRUE

RootLevelName	UFLSInstigatorName	Count of UFLS	Count of UFLS2
Generation		1	0%
	AGGREKO	24	4%
	Cabras 1	76	11%
	Cabras 2	45	7%
	Machche CT	46	7%
	NRG SOLAR	149	23%
	Piti 7 CT (TEM)	67	10%
	Piti 8 (MEC)	108	16%
	Piti 9 (MEC)	135	20%
	Yigo CT	11	2%
Generation Total		**662**	**100%**
Grand Total		**662**	**100%**

Graph 1 shows that NRG Solar totaled 149 events or 23% of the total UFLS generation outages. NRG Solar had the highest count by generation type of UFLS outages in 2019.

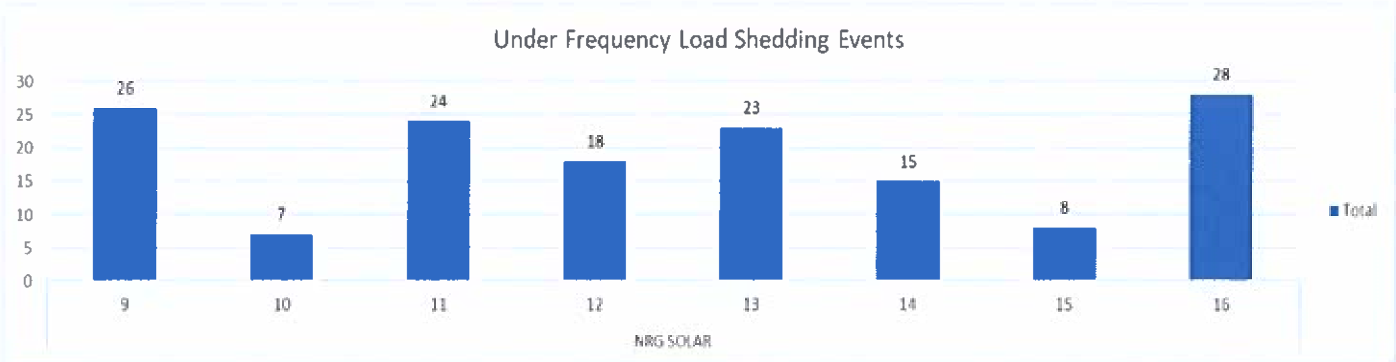
Graph 1 - Under Frequency Load Shedding Events for 2019 **count** by **Instigator**



Graph 2 shows the count of UFLS events by hour ending for NRG Solar. NRG Solar UFLS outages increase in frequency (of solar production) at the beginning of the day, mid-day and at the end of the day (hours ending 9, 11, 13 and 16) – When solar production is:

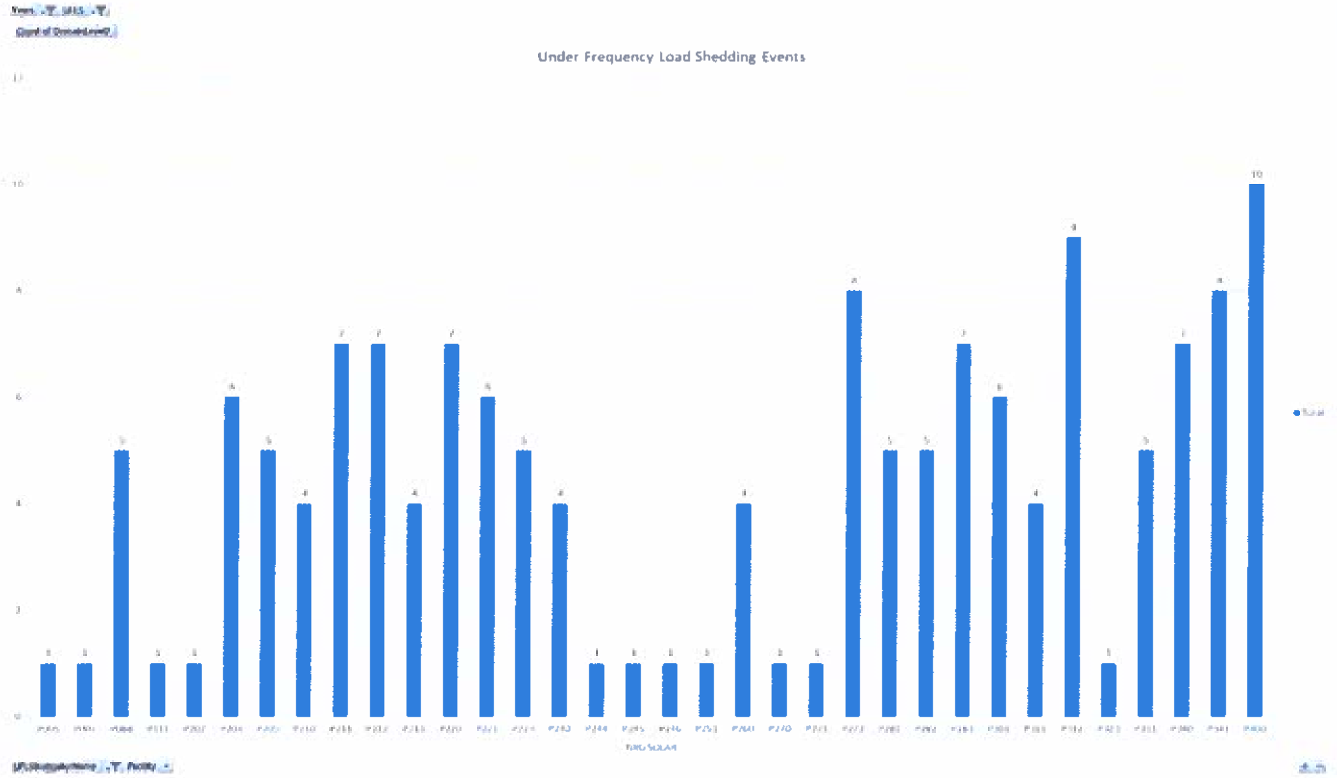
- Ramping up for the day
- At max daily production
- Ramping down for the day

Graph 2 - Under Frequency Load Shedding Events for 2019 **count** by **hour ending** for Instigator **(NRG SOLAR)**



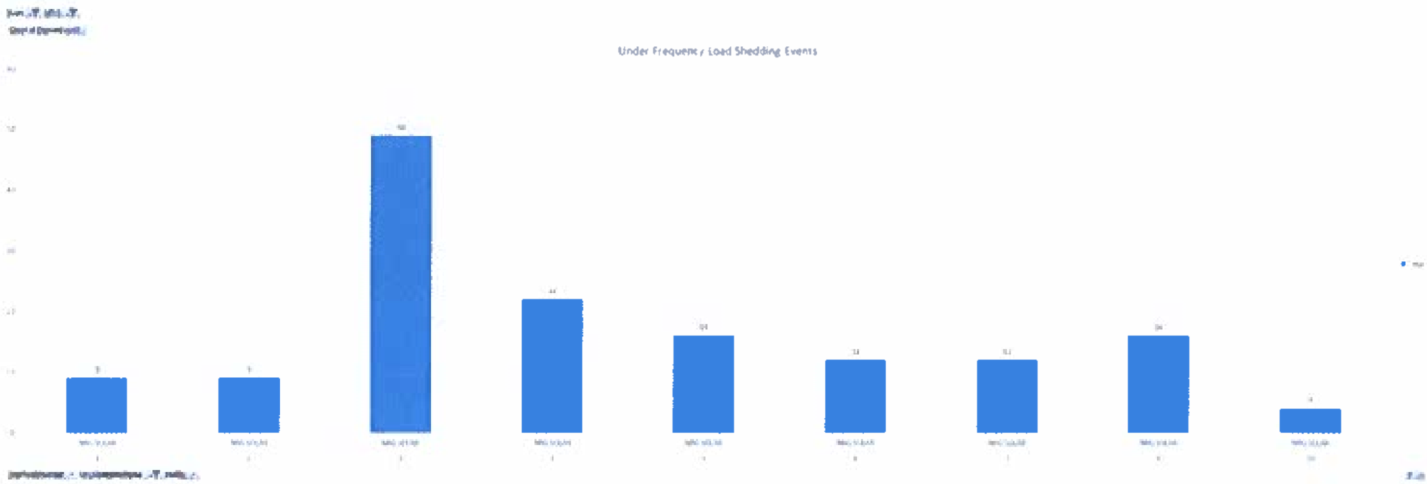
Graph 3 shows the count of UFLS events by feeder for NRG Solar. You can see that the number of UFLS events varies by feeder.

Graph 3 - Under Frequency Load Shedding Events for 2019 **count** by **feeder** for Instigator **(NRG SOLAR)**



Graphs 4 shows the UFLS by month. The data shows that March is the most likely month for UFLS events caused by solar. There were 49 UFLS events in March or 33% of the annual total. On average, March had 1.5 UFLS events every day compared to the annual average of 1 event every 2.4 days. According to GPA, March is the highest solar production month. This was confirmed with actual solar production data from Dandan solar facilities. The data shows that UFLS events increase as solar production increases.

Graph 4 - Under Frequency Load Shedding Events for 2019 **count** by **month** for Instigator **(NRG SOLAR)**



Graph 4.suport1 – UFLS solar events by Month

TripMonthNumber	Count of DomainLevel2
1	9
2	9
3	49
4	22
5	16
6	12
7	12
8	16
10	4
Grand Total	**149**

Graph 4.support2 – Solar production by Month

Dandan Solar Facility Monthly Production	
Month	Percent of Annual
Jan	7.7%
Feb	8.3%
Mar	10.0%
Apr	9.8%
May	9.1%
Jun	9.1%
Jul	8.9%
Aug	6.2%
Sep	7.6%
Oct	7.6%
Nov	7.7%
Dec	8.0%
	100.0%

Table 4 data is a summary of feeders to be studied. The chart 4 and chart 5 feeder data was summarized from the GPA maintained and provided Net Metering report.

Table 4 shows the feeders that UFS recommended that GPA conduct additional engineering study and analysis

UFS Recommendations on Engineering Feeder Study	
Feeder	UFS Notes
P-087	Has larger array installed, has higher total solar
P-220	Has high total solar (small max feeder)
P-322	Has larger array installed, has highest penetration of solar total kW installed
P-401	Has highest average sized solar installed (multiple 100 kW?)

Table 5 shows additional currently installed solar statistics for the recommended feeders to study. Additional engineering study to be completed by other. Preliminary data suggests that UFLS events increase with:

- Large single solar array installed on feeder (big install)
- Large total solar KW installed on feeder from multiple installs (many small installs)
- Feeder has high solar installations in relation to feeder maximum demand
- Feeder has high solar installations in relation to feeder minimum daytime demand

Table 5 – Current solar install statistics for feeders to be studied

Row Labels	Min of Size (kW)3	Average of Size (kW)3	Max of Size (kW)3	Sum of Size (kW)	Count of Size (kW)3	Sum of % of Maximum kW	Sum of % of Minimum Daytime kW
P-087	3	10	100	1,563	153	40%	62%
P-220	3	9	25	187	21	31%	97%
P-322	1	18	100	2,107	117	28%	55%
P-401	17	59	100	117	2	10%	17%

PAID

TREASURER OF GUAM
(671)475-1122/(671)475-1105

RECEIPT NO	9921008250
ORDER NO	123314738
DATE	04/06/2021 10:34
LOC/STATION	00/0000000000
PAY METHOD	CREDIT CARD/MASTERCARD
CARD NO	######0409
GRAND TOTAL	$632.98
CONVENIENCE FEE	$0.00

REFERENCE NO	#####1472
DOCUMENT NO	500WAGE
TAX TYPE	500WAGE
TAX MONTH	3
TAX YEAR	2021
AMOUNT	$632.98

CARDMEMBER ACKNOWLEDGES RECEIPT OF GOODS AND/OR SERVICES IN THE AMOUNT OF THE TOTAL SHOWN HEREON AND AGREES TO PERFORM THE OBLIGATIONS SET FORTH BY THE CARDMEMBER'S AGREEMENT WITH THE ISSUER.

FREDERICK HORECKY

TOP COPY-MERCHANT BOT COPY-CUSTOMER

Report Summary Observations

- Annual calculated dollar under recovery due to current installed solar $3.9 million
- There were 2,148 customers with behind the meter solar at as of November 2020
- There is a total of 25.4 MW of installed solar
- There are a total of 59 customers with battery storage (2.7% of customers)
- Total installed battery capacity is 674 kW (2.7% of installed solar capacity)
- 266 kW of the total battery installations were installed in 2020 (39.5% of total battery installs)
- The value of solar (VOS) had a prior UFS study value of 16 cents per kWh (rounded to 2 decimals)

This report is a summary of the Guam Power Authority's (GPA) **under recovery due to current installed solar.** The data in this study was supplied by GPA. The data was provided from the "Net Metering" file. This file is used by GPA to track customer installed generation details. The analysis was conducted using the then most recent, net meter listing through November 2020. The summary of this data was prepared by Utility Financial Solutions, LLC (UFS).

Table 1 – Behind the Meter Generation

Rate Class and Technology			
Technology	Schedule	Customer Count	Total kW
Solar Energy	R - Residential	2,011	19,168.46
	J - Gen Service Dmd	56	3,360.05
	K - Small Gov Dmd	9	317.80
	L - Large Government	2	122.80
	P - Large Power	10	940.70
	G - Gen Serv Non-Dmd	51	1,483.62
	S - Sm Gov Non-Dmd	7	78.80
Wind Turbine	R - Residential	2	3.60
Grand Total		2,148	25,475.83

Guam Power Authority
RFI-20

The value of solar assumptions from the prior UFS study are below. These assumptions and VOS calculation are in the process of being reviewed and updated. This report provides an up to date look for the current customer installed generation extended by the prior VOS study. The VOS calculation basics are LEAC + Distribution System Loss $ per kWh + Average kWh emissions. Since the VOS was calculated the same for each rate class, the under recovery is different based on the difference for respective rate class base rate.

Projection Date Ending	12/31/2020
Annual Compounded Degradation %	0.80%
Distribution System Loss $ per kWh	$ 0.00640
Average kWh emissions	$ 0.000039

RATE SCHEDULE	Base Rate	LEAC	VOS	under recovery (subsidy)
R	0.092931	0.154242	0.159681	0.087492
J	0.131121	0.154242	0.159681	0.125682
K	0.139322	0.154242	0.159681	0.133883
L	0.135248	0.154242	0.159681	0.129809
P	0.115389	0.154242	0.159681	0.109950
G	0.150836	0.154242	0.159681	0.145397
S	0.153341	0.154242	0.159681	0.147902

NREL Annual Production per DC KW rooftop solar	1421
DC to AC Ratio	1.2
Days per year	365
Average AC kWh produced per day	4.671781
Reference Average AC kWh produced per day per AC KW installed roof top solar	1,705

Table 2 shows the calculated annual under recovery by rate class. For example, the rate schedule R shows the largest annual dollar under recovery (subsidy). The calculation basics are to calculate the per kWh subsidy (Base Rate + LEAC) – VOS = under recovery (subsidy). The per kWh subsidy is then multiplied by the projected number of annual kWh production for each rate schedule. The projected annual kWh production is estimated by the applying an average 1,421 kWh production per KW DC of installed solar. Each customer is adjusted based on the age of their system by an annual degradation of .8% (eight tenths of one percent).

Table 2 – Summary of annual under recovery by rate schedule

Schedule	Average of under recovery (subsidy) / kWh	Sum of Projected Annual kWh Generated	Sum of Estimated Annual Subsidy	
G	$0.145	2,368,889	$	344,429
J	$0.110	4,666,005	$	586,433
K	$0.134	518,889	$	69,470
L	$0.130	203,743	$	26,448
P	$0.077	1,056,495	$	116,162
R	$0.087	30,982,251	$	2,710,700
S	$0.148	125,245	$	18,524
Grand Total	**$0.090**	**39,921,517**	**$**	**3,872,166**

Payment Summary

Thank you. Your transaction has been succesfully received.

RECEIPT NO	9921008250
ORDER NO	123314738
DATE	04/06/2021 10:34
PAY METHOD	CREDIT CARD/MASTERCARD
CARD NO	######0409
TOTAL AMOUNT	$632.98

Print Receipt Cancel