ADDING PV CAPACITY
INITIAL ASSESSMENT AND
RECOMMENDATIONS
FOR GALENA, ALASKA
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Funded by the
Alaska Center for Energy and Power
And by the
Department of Energy EPSCoR

Reviewed by Brian Hirsch,
National Renewable Energy Laboratory and
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Tanana Chiefs Conference

January 2014
Executive Summary

Solar PV electricity generation is of interest to the City of Galena to supplement electricity production with diesel electric generators. Several PV installations, totaling approximately 30 kW, are currently distributed throughout locations on the Galena distribution grid.

This report explores the potential for adding additional PV arrays on Galena’s grid while considering the current electricity generation infrastructure and making suggestions for future infrastructure upgrades.

It is found that the maximum amount of PV capacity that could currently be absorbed by the distribution grid totals 130 kW and that 110 kW would be a prudent maximum target for total capacity installed in the current situation. With proper automation of the powerhouse and central SCADA control over all generation assets (PV and diesel) the PV capacity can potentially be increased to 205 kW. However, additional studies of the grid and supply and demand dynamics are required to ensure that power quality will remain within acceptable bounds with this amount of PV power online.

Should the City of Galena decide to pursue the integration of large amounts of PV power in the future, it is recommended that a) data collection efforts regarding electricity and heat usage are brought under way as soon as possible, b) a grid assessment be performed with the goal of identifying needed improvements to accommodate distributed PV arrays, c) the powerhouse replacement be designed with accommodation of significant solar PV generation in mind, and d) that distributed residential solar PV installations be required to grid-tie with inverters that have communications and remote control capabilities.
Disclaimers

This report is intended for information only, not for design.

The data currently available for Galena, and the fact that the future configuration and capabilities of the Galena diesel powerhouse is not known at this time, does not allow for a reasonable in-depth PV integration study that would be suitable for investment decisions.
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Introduction

The City of Galena, Alaska is located on the Yukon River in the Alaskan Interior at latitude 64° 44' 26'' N. Electricity is supplied to Galena mainly by diesel electric generators, which rely on the shipping of diesel fuel on the Yukon River as Galena is not accessible by road. That is, the cost of diesel is high and so are environmental risks associated with shipping. In recent years, the city, and private entities have installed solar PV electric generators to a totaling approximately 30 kW of capacity distributed over several arrays.

The city recently has expressed interest in adding further solar PV capacity. Due to the intermittent nature of PV power, it is important to understand the limitations of the islanded diesel microgrid in accommodating additional solar PV capacity without detriment to grid stability.

This report details an initial exploration of possible options for adding additional solar PV capacity under several scenarios. The reason for using several scenarios is that the Galena powerhouse was heavily damaged in a flood in May 2013 and is likely to be replaced. Thus, recommendations are given on how to proceed, both with existing equipment, and under a scenario where the existing equipment is replaced.
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Current Situation

Currently, Galena is generating electricity using 450 kW and 800 kW diesel electric generator units. These units are manually dispatched, and automation capabilities of the powerhouse switchgear have been disabled.

Post-flood load levels are not quite clear as some residents have not yet returned. Monthly data exists for pre-flood years that can be used to roughly estimate load levels. Based on this data, the average load is 685 kW, with a range from 493 kW in June to 898 kW in January (see Figure 2.1). Based on hourly records kept by powerhouse operators, diurnal variation of load is approximately ±30% of the average load. These records also reveal that load levels in Galena have been declining between 2007 and 2009, and stable in 2010 and 2011 (the end of the record).
2. CURRENT SITUATION

Figure 2.1: Average (red) and peak (blue) loads by month for July 2011 to June 2012. Source: PCE Database, http://akenergygateway.alaska.edu
Adding PV

This section explores the maximum amount of solar PV generation that can be added to the system without risking under-loading conditions on the available diesel generators. Under-loading diesel generators for prolonged periods of time can damage the engine due to incomplete combustion and the exhaust system due to low exhaust gas temperatures.

A simple model, based only on available generation assets is employed. Note that this will give an absolute maximum envelope for addition of solar PV. Additional considerations are necessary regarding placement of such PV arrays in the distribution grid. This is not part of the scope for this exploratory study.

In the following it is assumed that a) the minimum optimal loading levels for the given generators is 30%, and that b) the spinning reserve capacity required in the system at all times is 75 kW.

3.1 PV Resource

The Alaskan Interior receives a fair amount of solar radiation between March and September. Particularly during March and April, solar irradiance is quite good, due to a clear atmosphere and high surface albedo. In addition, low temperatures can increase the efficiency of solar PV arrays significantly during this time. Figure 3.1 shows the monthly average irradiance on a fixed angle solar panel installed at 64.7°. During the winter months, when electricity consumption is highest, solar irradiance is generally poor.
3.2 PV Arrays with unknown Output

Uncontrolled PV arrays are installations that cannot be controlled by the powerhouse. That is, these arrays cannot be automatically curtailed, or their ramp rate adjusted, to meet optimal criteria for grid stability and minimum optimal loading for the generators online. Furthermore, the powerhouse control system is not aware of the power levels at the arrays, and thus they appear merely as negative load that can fluctuate suddenly. All PV arrays currently installed in Galena fall into this class.

For the case when the instantaneous output from PV arrays cannot be regulated by the powerhouse to ensure that diesel gensets are not underloaded, a worst-case assumption has to be made. That is, the maximum allowable amount of PV power on the grid cannot exceed the amount that could violate minimum loading requirements for a given load and generator combination online. Thus, to allow for minimum optimal loading levels to be guaranteed at all times, the total amount of solar PV on the Galena grid may not exceed 135 kW.

Reasons: The spinning reserve requirement of 75 kW requires that for a load of 375 kW, the 800 kW generator is providing power to the grid. The minimum optimal loading for this generator is $0.3 \cdot 800 \text{ kW} = 240 \text{ kW}$. The difference between the actual load and the minimum optimal loading gives the maximum allowable amount of solar PV capacity, that is, $375 - 240 = 135 \text{ kW}$.

3.3 PV Arrays with known Output

If the output of distributed PV arrays is known to the powerhouse, and if a dynamic and automatic diesel scheduling system exists, spinning reserve requirements can be varied in time depending on PV output. The calculus here is that the sudden and complete loss of all PV output is as likely as the sudden requirement of the spinning reserve. Thus, if the total PV power on the grid exceeds the spinning reserve capacity, the amount of PV power becomes the spinning reserve capacity. The current system, both at the powerhouse, and at the distributed PV arrays in Galena does not allow this approach.

If this level of dynamic control was implemented, the maximum allowable solar PV capacity would be 205 kW.
3.4 Addition of further solar PV capacity

Any further addition of solar PV capacity will require full control integration of PV arrays into the powerhouse SCADA system and scheduling algorithms. This will permit curtailing or diversion of solar power as needed to remain within the optimal operational envelope of the powerhouse. Furthermore, if a larger amount of PV capacity is intended to cogenerate with diesel generators, a small energy storage system may be required to control ramp rates of the PV systems in order to avoid detrimental effects on power quality.

Adding further solar PV capacity will require significant engineering: i) determination of suitable points of grid connection for large power flows, ii) coordination with new powerhouse design, from diesel fleet selection to control algorithm design, iii) study of grid dynamics to identify if power quality stabilization measures are required.
ADDITIO N OF FURTHER SOLAR PV CAPACITY

3.4. ADDITION OF FURTHER SOLAR PV CAPACITY

Figure 3.1: Solar irradiance on the plane of a fixed-tilt PV array installed at 64.7°, facing due South. Source: NREL PV Watts Viewer, with data for Huslia, AK.
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Recommendations

Since the current power generation situation in Galena is in flux, it is highly recom-
mended that a conservative approach be taken when adding additional solar PV capac-
ity. While this study shows that a total 135 kW of solar PV capacity could in theory be
installed, it would be prudent to be conservative. Hence, under the current situation,
it is recommended that the total solar PV capacity be capped at 110 kW, including
existing arrays.

If it is desired to add more solar PV capacity in the future, it is highly recommended
that appropriate steps be taken proactively to enable the Galena powerhouse and grid
to accommodate additional solar power in the future. These steps are outlined below.

Data Collection: For thorough assessment of the addition of significant solar PV
resources to the energy mix in Galena, it is absolutely critical that load (real and reactive)
data be collected for all feeders. In addition, line voltages and currents should be
collected to assess potential unbalanced phasing, which will aid in identifying weak-
nesses in the grid and avoid problems in integrating single phase residential type sys-
tems.

Data should be collected, at minimum, in 10 minute intervals. For detailed energy
balance and power flow modeling, one second intervals are desirable. Data logging
equipment should be of high quality and feature built-in redundancies to minimize
the risk of sustained data losses.

Grid Assessment: Integration of massively distributed PV capacity has lead to
significant problems in isolated microgrids in Hawaii. Distribution grids are generally
designed to transport power from the powerhouse to the consumer, not vice versa. It
is of great importance to understand the limitations of adding distributed PV capacity
in a given grid. Large, stand-alone PV installations, if poorly placed within the grid, can cause similar problems. A thorough grid assessment, in conjunction with detailed data collection will help determine optimal placement of PV capacity within the grid.

**Powerhouse Replacement Planning:** The key to optimal cogeneration of variable resources is to take a holistic view of all generation sources, and their limitations, and plan accordingly for their integration into the energy mix. In the case of Galena, this means, that a replacement powerhouse should be equipped with adequate control algorithms and communication equipment to accommodate significant PV penetration. Furthermore, sizing of the generator fleet according to load and PV potential can significantly improve the interplay of the powerhouse and variable solar resource and maximize the benefits of renewable energy.

Addition of a small ‘power class’ energy storage system should be considered if very large amounts (> 60% of typical summer noontime load) of PV are desired to be integrated. Such a system can aid in the mitigation of steep ramp rates due to cloud events, but will impact the economics of the system.

**Inverter Selection for Residential Systems:** If significant amounts of PV capacity is to be installed at the residential level, it is important to ensure that the powerhouse control system can communicate with the grid-tie inverters of these systems. Only systems using inverters that can be controlled from the powerhouse should be allowed to connect with the grid.