Solar PV-Thermoelectric Generator Hybrid System for the Town of Faro Airport Beacon

Status Report

May 20, 2010

Yukon Energy, Mines and Resources

energy solutions centre

PROJECT OVERVIEW

This project involved the installation of a photovoltaic system (sometimes called solar electric or PV) to offset the use of the propane generator used to power one of the two Town of Faro's airport hazard beacons. These beacons are essential to the operation of the Faro Airport and are required to be on at all times.

The isolated nature of these beacons requires a reliable and low maintenance remote power source to be used. In the former configuration a very reliable, but relatively low efficiency, propane fuelled "Thermoelectric" generator (TEG) was connected to a battery bank and the generator and battery bank worked in combination to ensure that the beacon had adequate power to operate at all times.

The addition of solar photovoltaic panels and power conditioning equipment (including a new, larger battery bank) to this system is intended to allow the TEG to be shut down for significant portions of the year and offset the fuel used by the generator, thus reducing operating costs as well as greenhouse gas emissions.

This project will also act as a demonstration of how PV technology can be used in a remote application in the north.

Partners

This project was executed through a partnership between the Yukon Government's Energy Solution Centre (ESC) and the Department of Highways and Public Works Aviation Branch:

1. **The Energy Solutions Centre:** The Energy Solutions Centre (ESC) is a branch of the Yukon Government committed to the promotion of renewable energy and energy efficiency in the Yukon. ESC provided the bulk of the capital cost of this project and ongoing technical support as required.

2. **Aviation Branch:** The Aviation Branch of the Yukon Government develops and operates four airports and twenty-five aerodromes throughout the Yukon, including the community aerodrome in the Town of Faro. The Aviation Branch was responsible for the installation of the system and is the final owner of the system. The Branch will undertake the ongoing care and maintenance of the system in the future.

Breakdown of Responsibilities

Energy Solutions Centre:

- All capital costs associated with the purchase of materials for the project including any costs not included in the Global Thermoelectric quote (pole, wiring)
- Design of the PV solar energy system to be added to the existing thermoelectric generator (not including the integration of the system into the existing thermoelectric generator controls)
- Technical support, as required, for the design, installation and ongoing operation of the system

Aviation & Marine Branch:

- Technical support in the design of the PV solar system
- Design of any special controls required to integrate the PV system into the existing thermoelectric generator
- Installation of the system
- Ongoing care and maintenance of the system

PROJECT DETAILS

Propane consumption

The two hazard beacons at the Faro airport use approximately 6,850 litres of propane fuel per year, resulting in a total annual cost of approximately $3,600. The PV system is estimated to save as much as 50% of the propane consumed by the beacon converted for this project.

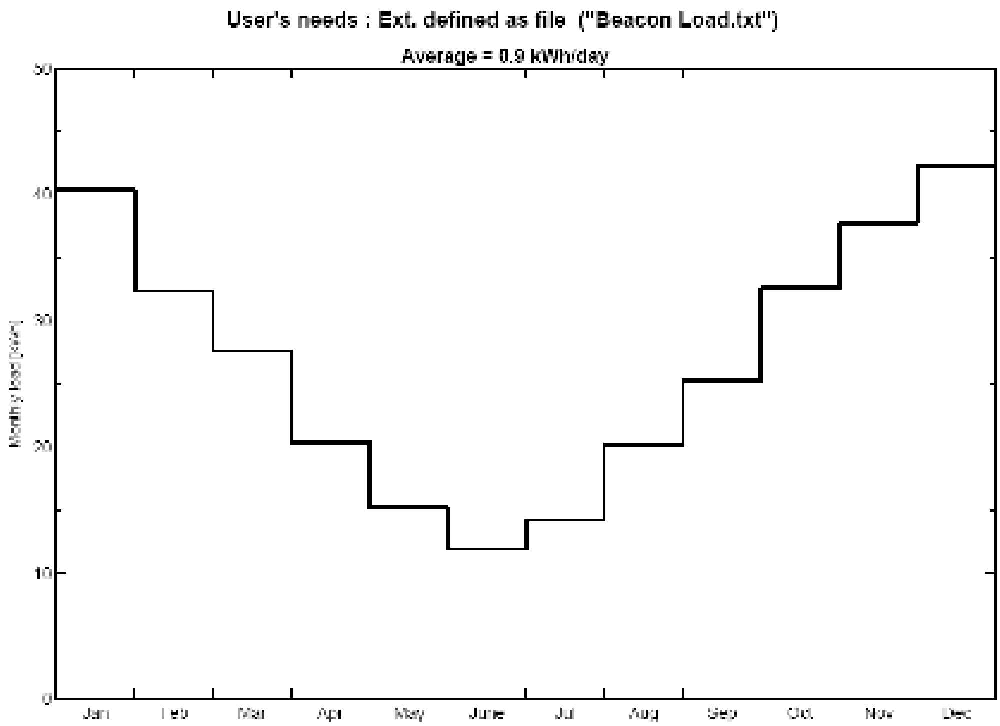
Beacon Load

The Faro hazard beacon draws 75 watts of electricity when operating and operates from dusk till dawn every day of the year. In an effort to reduce cycling on and off in the TEG and ensure reliability of the system the relatively inefficient propane generator is operated 24 hours a day, 365 days a year.

As the hours of daylight decrease over the course of the year the total energy requirements of the system increase. The table below gives an estimate of the total load on the system over the course of the year.

Ext. defined as file ("Beacon Load.txt"), average = 0.9 kWh/day

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year	
40.4	31.3	27.9	20.6	15.4	11.9	14.1	19.9	25.1	32.3	37.6	41.9	318	kWh



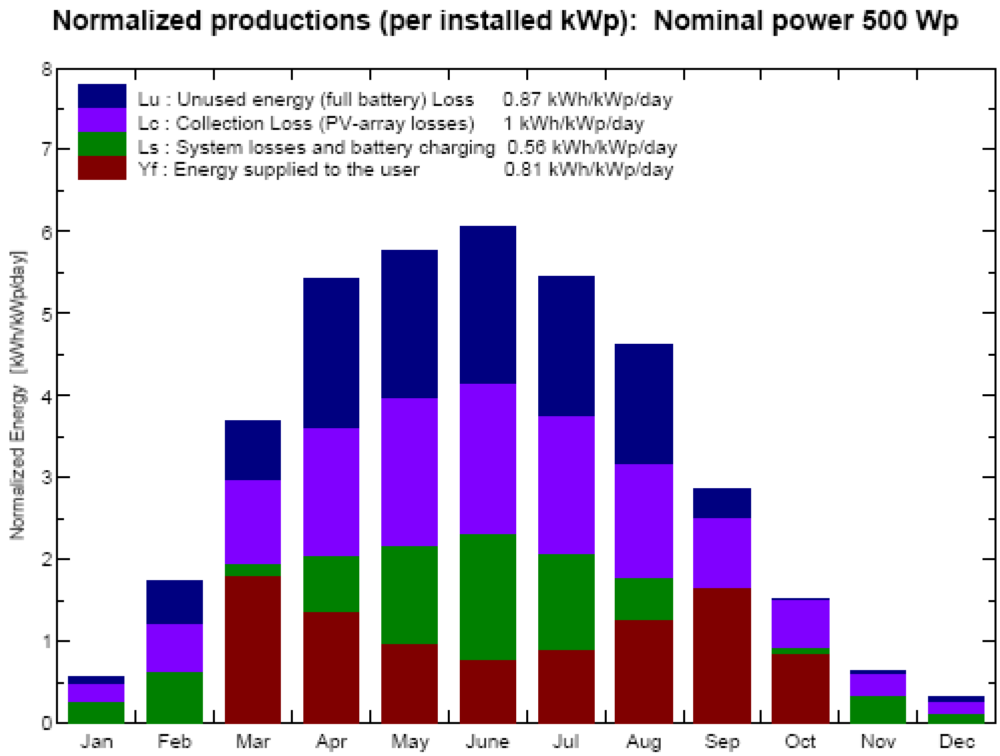
The increased load in the winter months coupled with decreased daylight hours make it difficult for a PV system to meet the energy needs of this system 12 months of the year; however, the relatively small summer loads along with high levels of summer sunlight make it possible for this system's energy requirements to be met solely by a PV system during the summer months.

Proposed System Design and Performance

In order to best meet the needs of the system while balancing capital costs the following system design was initially recommended by the Energy Solutions Centre staff:

- 500 Watts (nominal) of photovoltaic panels
- Support structure for panels
- Charge controller with maximum power point tracking capabilities
- TEG auto start kit which will allow the propane generator to turn off when not required

Simulations of the performance for this proposed system show that the solar panels would be able to provide 100 percent of the beacon's power demand from March through September and part of October (details of this simulation are given in the figure below). Efforts to design a PV system which could meet a larger portion of the annual demand proved uneconomical given the increase in winter load and significant decrease in winter solar resource.



Simulation variant

Balances and main results

	GlobHor kWh/m²	GlobEff kWh/m²	E Avail kWh	EUnused kWh	E Miss kWh	E User kWh	E Load kWh	SolFrac
January	10.8	16.9	5.16	1.04	0.00	0.00	0.00	1.000
February	30.1	47.2	16.16	7.35	0.00	0.00	0.00	1.000
March	78.6	110.7	41.44	11.06	-0.01	27.91	27.90	1.000
April	130.7	157.9	58.10	27.20	-0.01	20.56	20.55	1.000
May	165.1	173.2	61.50	27.72	-0.01	15.38	15.38	1.000
June	174.7	176.1	63.25	28.49	-0.00	11.93	11.93	1.000
July	161.6	163.6	58.71	26.36	-0.01	14.11	14.10	1.000
August	128.7	138.7	50.10	22.52	-0.01	19.88	19.88	1.000
September	74.0	82.9	30.49	5.31	-0.01	25.06	25.05	1.000
October	36.9	45.5	14.45	0.02	18.85	13.48	32.33	0.417
November	13.3	18.9	5.80	0.56	0.00	0.00	0.00	1.000
December	6.0	9.3	2.57	0.52	0.00	0.00	0.00	1.000
Yearly sum	1010.4	1140.8	407.74	158.15	18.79	148.31	167.10	0.888

Legends:

GlobHor	Horizontal global irradiation	E Miss	Missing energy
GlobEff	"Effective" Global, corr. for IAM and shadings	E User	Energy supplied to the user
E Avail	Available Solar Energy	E Load	Energy need of the user (Load)
EUnused	Unused energy (full battery) loss	SolFrac	Solar fraction (EUsed / ELoad)

Global Thermoelectric Equipment Recommendations and Costs

The existing thermoelectric generator was manufactured by Global Thermoelectric who also offers PV hybrid systems. They where asked to recommend a system design and provide a quote for this project. They provided the two following options for upgrade:

Option 1: Auto start Option

Item	Qty.	Description	Unit Price (CDN$)	Total Price (CDN$)
1	1	5120 Remote/Auto Start Upgrade Kit	$2,023.00	$2,023.00
2	1	5 x 165W Solar Panels (Model 3165N BP) c/w mounting frame, junction boxes & controller & 600 AH Battery Bank and Outdoor Enclosure, Project Documentation	$10,290.00	$10,290.00
			Total Ex-Works Bassano, Canada	**$12,313.00**

This system would include an auto start upgrade to the existing TEG so that the TEG could shut itself off anytime the batteries had been fully charged by the PV system. This would result in a significant decrease in energy consumption; however it would add complexity to the system and could decrease the TEG lifespan.

Global Thermoelectric has predicted the TEG energy consumption with this system should be 660 litres per year; a very significant decrease from the estimated 3,400 litres currently consumed.

Option 2: Manual Operation

Item	Qty.	Description	Unit Price (CDN$)	Total Price (CDN$)
1	1	5 x 165W Solar Panels (Model 3165N BP) c/w mounting frame, junction boxes & controller & 600 AH Battery Bank and Outdoor Enclosure, Project Documentation	$10,290.00	$9,090.00
			Total Ex-Works Bassano, Canada	**$9,090.00**

This is Global Thermoelectric's basic solar electric upgrade and would be manually operated, requiring someone to physically turn the TEG on in the fall (when the solar resource is low) and off again in the spring (when the PV system can meet the entire load of the system). In this configuration the PV system would provide no benefit to the system during the winter months.

Global Thermoelectric has predicted the TEG energy consumption with this system should be 1,806 litres per year.

Projected Project Payback

The above analysis predicts that the addition of these PV panels would give the following fuel cost savings and simple payback period:

	Estimated Fuel Consumption (litres)	Annual Fuel Savings (litres)	Estimated Costs Savings	Capital Cost	Simple Payback (years)
Existing System	3,425		$ -		
Option 1: Manual Start-up	1,806	1,619	$ 858.07	$ 9,090.00	10.6
Option 2: Auto Start-up	660	2,765	$ 1,465.45	$ 12,313.00	8.4

The estimated net greenhouse gas reduction for this project is 4.3 tonnes for Option 1 and 2.5 tonnes for Option 2 of CO_2 equivalent emissions per year.

Installed Equipment

Based on the above analysis and discussions with operations and maintenance staff it was decided that Option 1 with the auto start ability was the best use of capital dollars for this project.

The system was purchased in the fall of 2008 and installed in the fall of 2009.

The current operating plan will include shutting down the auto start function at some point during the winter to reduce excessive cycling of the TEG and premature equipment failure. For this reason actual reductions in the volume of fuel used by the system were predicted to fall somewhere between the two options given above.

Actual Costs

After receiving the equipment from Global Thermodynamic it was realised that some additional mounting and balance of system components would be required to convert the existing TEG to incorporate the new PV system. Actual final costs for the system were as follows:

Description	Price
5 x 165W Solar Panels (Model 3165N BP) c/w mounting frame, junction boxes & controller & 600 AH Battery Bank and Outdoor Enclosure, Project Documentation	$10,290.00
5120 Remote/Auto Start Upgrade Kit	$2,023.00
Light Standard Base	$800.00
Misc. Parts	$2,616.59
Total	**$15,729.59**

Project Status

The PV system was installed in late August of 2009 and has been in operation through the winter and spring of 2009/2010. An interim assessment of cost savings and system performance will be conducted in the fall of 2010 – after a full year of operation.

A complete analysis of the true costs and benefits of this system will be conducted after two years of full operation at which time a final project report will be completed and consideration will be given to the addition of a PV component to the second Faro beacon.

Appendix A:

Detailed PVSyst Report

Stand alone PV system: Main results

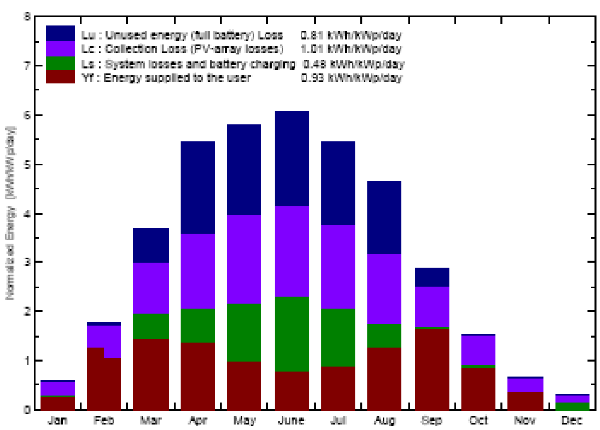
Project : **Airport Beacon**

Simulation variant : **Simulation variant**

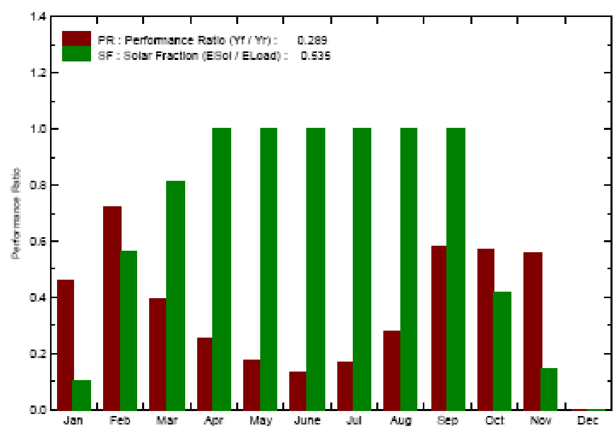
Main system parameters	System type	**Stand alone**		
PV field orientation	Tilt	30°	Azimut	0°
PV modules	Model	BP 3125	Pnom	125 Wp
PV array	Nb of modules	4	Pnom total	**500 Wp**
Battery	Model	TXE 225 / OPzS200	Technology	vented, tubular
Battery pack	Nb of units	12	Voltage / Capacity	**12 V / 440 Ah**
User's needs	Ext. defined as file	Beacon Load.txt	Global	318 kWh/year

Main simulation results				
System production	**Available Energy**	**406 kWh/year**	Specific	812 kWh/kWp/year
	Used energy	170 kWh/year	Excess (unused)	148 kWh/year
	Performance ratio PR	28.9 %	Solar fraction SF	53.5 %
Loss of load	Time fraction	39.5 %	Missing energy	148 kWh

Normalized productions (per installed kWp): Nominal power 500 Wp



Performance Ratio and solar fraction



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March	78.6	110.7	41.12	10.43	5.25	22.65	27.90	0.812
April	130.7	157.9	58.10	27.20	-0.01	20.56	20.55	1.000
May	165.1	173.2	61.50	27.72	-0.01	15.38	15.38	1.000
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November	13.3	18.9	5.73	0.05	32.11	5.47	37.58	0.145
December	6.0	9.3	2.63	0.03	41.85	0.00	41.85	0.000
Yearly sum	1010.4	1140.8	406.14	148.21	147.91	170.24	318.15	0.535

Legends:

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Stand alone PV system: Loss diagram

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Loss diagram over the whole year