Hybrid Diesel-Solar Case Study

Summary

The following case study was prepared based on data collected from publicly available 43101 reports in order to demonstrate the benefits of installing a utility scale solar-diesel hybrid system at a road accessible mine in Northern Canada.

Diesel – Solar Controllers

The conventional wisdom regarding the incorporation of solar photovoltaics (PV) into isolated grids or micro grids states that a maximum of 20% of the energy on the grid can be provided by PV due to the fluctuating nature of PV power generation. This limit is referred to as maximum PV penetration. However, with the development of diesel – solar controllers the maximum PV penetration level can now be raised to 60%. Using a complex automated SCADA platform, diesel – solar controllers maintain minimum loading parameters for diesel generators (usually 40%) while using available PV power as peak loading capacity. When the sun is shining and micro-grid is at peak capacity the controllers enable PV to provide up to 60% of grid capacity minimizing diesel consumption. Should the demand on the grid suddenly drop the controller instantly throttles the PV array to maintain the 40% loading parameters on the generator and if necessary shuts off the PV power plant entirely. Inversely, should clouds or dawn/dusk significantly reduce the available PV output, the controllers use the diesel generators spinning reserve to instantly pick up the additional load while maintaining grid stability.

These controllers allow for large utility scale PV systems to be connected to isolated grids providing maximum PV penetration without the use of batteries, significantly lowering the installed cost and providing a lower levelized cost of energy to the grid.

For further details on how diesel solar controllers work please see the Appendix C for a link to SMA's solar controller video..

Methodology

The following methodology was used to model both scenarios outlined below:

1. Using www.sedar.com, Solvest verified the following information pertaining to northern Canadian mining operations; power plant sizes, number of generators, electrical load analysis, cost per kWh, and cost per litre of diesel delivered to site.
2. This information was then imputed into HOMER Energy Modeling Software and RETScreen along with the parameters for the proposed energy storage system in order to determine the fuel savings and operational cost reductions. Efficiency losses for each of the proposed components were factored in allowing for accurate energy usage calculations.

The case study below demonstrates the impact of an solar-diesel hybrid solution at a heap-leach gold operation in northern Canada.

Case 1: Mine operating on diesel power plant only.

Assumptions:

- 7.5 MW maximum diesel generator capacity consisting of 5 x 1.5 MW Caterpillar Generators (Please see Appendix A for product specifications).
- Power plant operates 4 x 1.5 MW generators with an additional generator to provide peak load capacity if required.
- Cost per litre of diesel delivered to site is $0.90 per litre including onsite handling costs.
- Total electrical consumption is 52,000 kWh per day.
- Cost per kWh for electrical generation including diesel cost, capital replacement costs for the power plant, transmission costs, and maintenance is 24 cents per kWh.

Please note all prices are CAD.

Electrical Supply Costs

Power Plant Size	Base Load Capacity	Additional Capacity	Daily Electrical Consumption	Cost per kWh	Annual Operating Cost
7.5 MW	4 x 1.5 MW Generators	1 x 1.5 MW Generator	52,000 kWh	24 cents CAD	$4,555,200 CAD

Case 2: Mine operating with 3 MW Solar Diesel Hybrid Solution.

Assumptions:

- 7 MW maximum diesel generator capacity consisting of 5 x 1.5 MW Caterpillar Generators (Please see Appendix A for product specifications).
- Power plant operates with a continuous base load of 5.2 MW and an additional 1.8 MW induction reserve capacity.
- Cost per litre of diesel delivered to site is $0.90 per litre including onsite handling costs.
- Mine electrical consumption is 52,000 kWh per day.
- Cost per kWh for electrical generation including diesel cost, capital replacement costs for the power plant, transmission costs, and maintenance is 24 cents per kWh.
- 3 MW AC PV power plant installed on fixed 45-degree racking modeled at an average irradiance level of 2.74 kWh per meter squared (Please see Appendix B for further details).
- Diesel – Solar Controller installed that maintains a minimum generator load of 40%. While allowing for instant spinning reserve if the solar output suddenly decreases providing firm power without the need for batteries.
- Diesel – Solar Controller allows for maximum PV penetration of 60% with the PV power plant acting a s peak load capacity during daylight hours.
- Carbon offset credits valued at $50 per tonne of CO2.

Design Criteria:

- PV power plant sized to provide 60% grid penetration at peak operating capacity.
- Diesel – Solar Controller units installed at the diesel power plant and PV power plant using powerline communications to operate the SCADA platform.
- Generators operate continuously at 40% during daylight hours, and provide 100% of the load during the night.
- High efficiency bi-facial modules used to maximize the power production of the PV power plant while minimizing the project footprint.
- Single axis trackers used to provide a consistent daily power curve during daylight hours.
- Integrated remote monitoring allows manufacturers to fix many of the potential hardware problems online without traveling to site. This technology also allows for remote monitoring of the daily power production.

Based on the criteria outlined above, the proposed PV power plant design consists of 10,000 x 350W modules mounted on fixed tilt racking with a diesel – solar controller for a maximum grid penetration level of 60%.

Electrical Supply Costs

Base Load Capacity	**Additional Capacity**	**PV Power Plant AC Capacity**	**Daily Electrical Consumption**
4 x 1.5 MW Generators	1 x 1.5 MW Diesel Generators	3 MW	52,000 kWh
Annual PV Generation	**Carbon Credit Revenue**	**Cost per kWh**	**Annual Operating Cost**
4415 MWh	$174,000.00 CAD	24 cents CAD	$3,320,893.00 CAD

Budget

The following table contains the estimated budget for the proposed project. This budget was estimated conservatively in order to present a high cost scenario. Many of these costs can be lowered with proper project planning and co-ordination.

Description	**Cost**	**Notes**
PV Modules	$2,200,000.00	High Efficiency 72 Cell Modules
Inverters/Grid Connection Equipment	$650,000.00	String Inverters, AC combiners, Transformer, Switchgear
Balance of System	$300,000.00	Disconnects, Breakers, Cabling, fittings, etc.
Diesel Solar Controller	$500,000.00	Control modules for diesel generators and PV Power Plant

Racking	$800,000.00	Fixed 45 Degree Tilt Angle Racking
Installation Costs	$700,000.00	Includes all labour and electrical installation costs.
Shipping/Logistics	$300,000.00	Shipping costs for required materials from manufacturers to site.
Project Management and Engineering	$500,000.00	This includes all design, engineering, and project management costs.
Total Cost:	**$5,950,000.00 CAD**	**Plus applicable taxes.**

Key Benefits:

1. Reduce diesel consumption related to electrical generation by 23.6% annually.
2. Provide maximum PV penetration while maintaining grid stability.
3. Reduce operating costs by $1,234,307.00 CAD per year.
4. Minimize the impact of carbon taxes by reducing diesel consumption.
5. Improve the environmental image and public perception of the exploration project.
6. Solvest in partnership with RBC offers utility scale leasing options with terms ranting from 2 to 5 year, allowing for the entire cost of the system to be written off as an operating expense.

We trust that the foregoing information is satisfactory and details the benefits our proposed technology could add to your operations, please do not hesitate to contact the undersigned.

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The following pages contain the supporting appendixes for this proposal

Appendix B: CAT 1.5 MW Generator Fuel Consumption

STANDBY 1750 ekW 2188 kVA

60 Hz 1800 rpm 480 Volts

TECHNICAL DATA

Open Generator Set - - 1800 rpm/60 Hz/480 Volts	DM7958	
Low Fuel Consumption		
Generator Set Package Performance		
Genset Power rating @ 0.8 pf	2187.5 kVA	
Genset Power rating with fan	1750 ekW	
Coolant to aftercooler		
Coolant to aftercooler temp max	82 ° C	180 ° F
Fuel Consumption		
100% load with fan	470.0 L/hr	124.2 Gal/hr
75% load with fan	363.5 L/hr	96.0 Gal/hr
50% load with fan	256.5 L/hr	67.8 Gal/hr
Cooling System[1]		
Air flow restriction (system)	0.12 kPa	0.48 in. water
Air flow (max @ rated speed for radiator arrangement)	1671 m^3/min	59011 cfm
Engine Coolant capacity with radiator/exp. tank	398.0 L	105.1 gal
Engine coolant capacity	233.0 L	61.6 gal
Radiator coolant capacity	165.0 L	43.6 gal
Inlet Air		
Combustion air inlet flow rate	155.8 m^3/min	5502.0 cfm
Exhaust System		
Exhaust stack gas temperature	512.8 ° C	955.0 ° F
Exhaust gas flow rate	428.1 m^3/min	15118.2 cfm
Exhaust flange size (internal diameter)	203.2 mm	8.0 in
Exhaust system backpressure (maximum allowable)	6.7 kPa	26.9 in. water
Heat Rejection		
Heat rejection to coolant (total)	1028 kW	58462 Btu/min
Heat rejection to exhaust (total)	1960 kW	111465 Btu/min
Heat rejection to aftercooler	321 kW	18255 Btu/min
Heat rejection to atmosphere from engine	142 kW	8076 Btu/min
Heat rejection to atmosphere from generator	86.3 kW	4907.9 Btu/min
Alternator[2]		
Motor starting capability @ 30% voltage dip	5077 skVA	
Frame	1602	
Temperature Rise	125 ° C	225 ° F
Lube System		
Sump refill with filter	401.3 L	106.0 gal
Emissions (Nominal)[3]		
NOx g/hp-hr	10.52 g/hp-hr	
CO g/hp-hr	1.41 g/hp-hr	
HC g/hp-hr	.04 g/hp-hr	
PM g/hp-hr	.077 g/hp-hr	

Appendix B: Solar Irradiance Data

The following table is available through the RetScreen modelling software and was prepared by NASA. This table displays the weather data for Mayo Yukon:

Country - region		Canada	
Province / State		Yukon	
Climate data location		Mayo Airport	
Latitude	°N	63.6	
Longitude	°E	-135.9	Source
Elevation	m	504	Ground
Heating design temperature	°C	-45.4	Ground
Cooling design temperature	°C	25.0	Ground
Earth temperature amplitude	°C	25.4	NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	-23.3	79.0%	0.20	89.1	1.4	-22.1	1,280	0
Feb	-17.3	77.3%	0.89	89.3	1.8	-19.5	988	0
Mar	-9.2	68.3%	2.34	89.3	2.6	-15.4	843	0
Apr	1.3	57.6%	4.15	89.4	2.6	-6.0	501	0
May	8.8	53.9%	5.31	89.6	2.4	3.6	285	0
Jun	15.0	55.8%	6.00	89.7	1.9	12.4	90	150
Jul	16.2	63.8%	5.47	89.9	1.6	13.7	56	192
Aug	12.9	69.3%	4.19	89.8	1.5	9.8	158	90
Sep	6.2	73.1%	2.60	89.5	1.9	2.2	354	0
Oct	-2.7	77.9%	1.22	89.1	2.3	-7.2	642	0
Nov	-16.0	79.7%	0.35	89.0	1.7	-17.7	1,020	0
Dec	-19.5	80.1%	0.08	89.0	1.6	-19.9	1,163	0
Annual	-2.2	69.6%	2.74	89.4	1.9	-5.4	7,380	432
Source	Ground	Ground	NASA	NASA	Ground	NASA	Ground	Ground
			Measured at	m	10	0		

Appendix C: SMA Diesel Solar Controller

The following video contains a detailed description of the benefits and workings of a diesel solar controller: https://www.youtube.com/watch?v=eK73eXvXRvE