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International R&D Collaboration on Photovoltaic Hybrid Systems within Mini-grids

Project Manager: Josef Ayoub
CanmetENERGY, Varennes Research Centre

INTRODUCTION

Canada has over 300 remote communities that rely primarily on diesel gensets with high generation costs to produce electricity ($0.13-$2.45 per kWh in the Northwest Territories [1]). Meanwhile, electricity generation costs from grid-connected photovoltaics (PV) range from roughly C$0.38/kWh to C$0.75/kWh [2] and have been decreasing steadily. Thus, for many communities, PV and other renewables present an economic option for both lowering electricity costs and greenhouse gas emissions.

This project investigated technical and non-technical barriers to large scale integration of photovoltaic systems in remote communities. It built on CanmetENERGY's expertise developed through previous projects on wind-diesel and PV hybrid systems, and on Canada's participation in Task 11 of the International Energy Agency's (IEA) Photovoltaic Power Systems (PVPS) Implementing Agreement on "PV Hybrid Systems within Mini-grids ". This project lead to the development and study of Canada's first battery-free PV-diesel mini-grid in the Nemiah Valley of British Columbia and to Canadian contributions to IEA PVPS Task 11 reports examining best practices and challenges in PV mini-grid design and operation.

ACTIVITIES & RESULTS

Nemiah Valley mini-grid field demonstration

In the Fall of 2007, Canada's first battery-free photovoltaic(PV)-diesel mini-grid was implemented in the Nemiah Valley of British Columbia, home of the Xeni Gwet'in First Nation (see Figure 3). 27.36 kW of distributed photovoltaics were installed on the roofs of six houses, and have been supplying 11% of the community's yearly electricity needs (see Figure 4). As shown in Figure 5, loads in this community are relatively small (peak load of ~75 kW), so that photovoltaic penetration on this mini-grid is much higher than what has been achieved in any large-scale centralized grid: the 27.36 kW of PV represent 36% of peak load. The grid's energy efficiency was also improved by replacing what was essentially a "dump load" operated to keep the main (95 kW) gensets sufficiently loaded during weeknights and weekends by reduced weeknight/weekend loads supplied by a smaller (30 kW) genset ([3]).

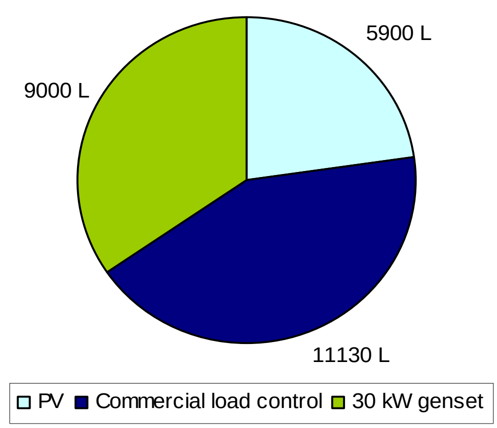
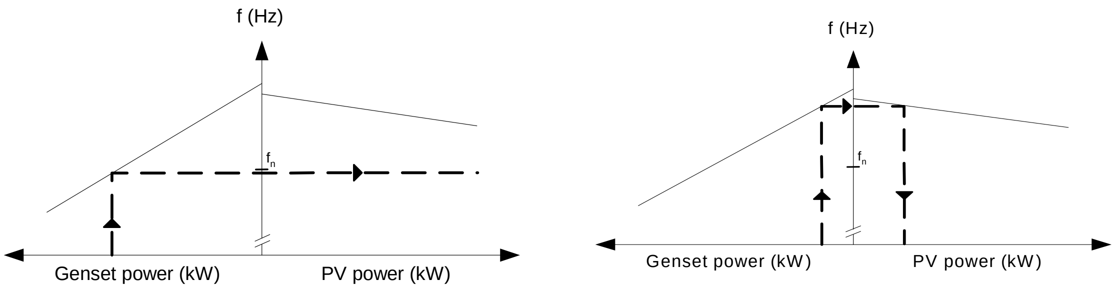


Figure 1: Fuel savings (in litres) from each of the three measures implemented in the Nemiah Valley mini-grid.

These measures lead to fuel savings of about 26,000 L per year (see Figure 1) and to 73 tonnes of avoided GHG emissions per year – the equivalent of taking 1 car off the road per household connected to the mini-grid! This study highlighted the need to better understand genset behaviour at low loading, and to consider alternatives to costly "dump loads" in similar systems. With respect to system performance, the main issue encountered was the occurrence of conditions under which PV output would, if not curtailed, exceed system load. It was estimated that the PV system would deliver about 10% more energy on a yearly basis if all of its output could be absorbed (as in the case of connection to a large, centralized grid). A number of avenues for mitigating this loss were explored, such as the one illustrated in Figure 2.

Canada



(a) No PV Curtailment

(b) PV Curtailment

Figure 2: One option for PV power curtailment to match generation with demand in the Nemiah Valley: the generation plant could implement a frequency droop characteristic that would signal to the photovoltaic inverters to reduce their generation. In Figure 2(a), the power delivered by the genset is relatively high, consequently the genset is operating at a frequency slightly lower than nominal, indicating that the genset is loaded. The PV curtailment is set to engage only when the frequency rises above nominal, consequently all available PV power can be returned to the grid. In Figure 2(b) the genset is very lightly loaded and is then operating at a significantly higher than nominal frequency. The inverters measure that frequency and curtail their power down according to their pre-programmed droop characteristic. If the genset power continues to drop, the frequency will continue to rise up to the point where the PV power will drop to zero.

Figure 3: Aerial view of the PV-diesel mini-grid in the Nemiah Valley, British Columbia: PV systems and a diesel genset supply electricity to commercial and residential zones.

Figure 4: Residential PV systems and diesel gensets supplying the Nemiah Valley mini-grid (Credit: Dave Turcotte and Andrew Swingler).

IEA PVPS Task 11 on « PV Hybrid Systems within Mini-grids »

The International Energy Agency Photovoltaic Power Systems Programme (IEA PVPS) Task 11 brings together researchers from 13 countries to investigate "PV Hybrid Systems within Mini-grids". Questions tackled by Task 11 members include how to ensure the stability and power quality of PV mini-grids, particularly with high PV penetrations, as well as how to best design and operate such systems given trade-offs between economic, environmental and reliability considerations. Canadian participants have contributed to Task 11 reports [6-12] and presentations on issues such as PV mini-grid control methods, design and simulation tools, performance indicators and case studies on sustainable development considerations in PV mini-grids.
www.iea-pvps-task11.org

Discussion & Next Steps

CanmetENERGY is continuing research on renewable energy mini-grids, such as that in Hartley Bay, British Columbia, where demand response strategies are being investigated to facilitate the integration of a small hydroelectric project in the mini-grid. A tool to optimize diesel genset dispatch has also been developed, and CanmetENERGY aims to popularize this tool and its research findings to facilitate large-scale deployment of renewables in Canada's remote communities.

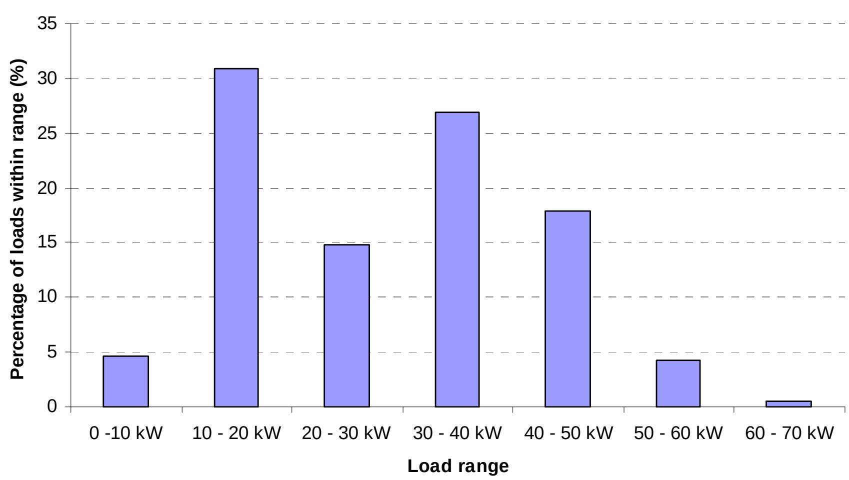


Figure 5: Profile of the total load (PV not subtracted) for the Nemiah Valley mini-grid during the November 19, 2008 to November 18, 2009 period, indicating percentage of total loads within a given range.

Budget

F31.002 (2007-2012)

PERD	Other Federal	External in-kind	External Cash	Leverage
1029 k$	100 k$	2075 k$	—	184 %

Project Team

Project Team Members/Organizations

Canada:

- Lisa Dignard-Bailey, Josef Ayoub, Farid Katiraei, Sophie Pelland and Dave Turcotte (CanmetENERGY)
- George Colgate (Xeni Gwet'in Enterprise)
- Konrad Mauch (KM Electrical Services)
- Luiz Lopes (Concordia University)
- Andrew Swingler (Schneider Electric)

International:

- Spain: Xavier Vallve (TTA)
- Germany: Georg Bopp (Fraunhofer ISE), Michel Vandenbergh (ISET) and Michael Mueller (Steca Gmbh)
- France: JC Marcel (Transénergie) and Xavier LePivert (Ecole des Mines de Paris)
- Japan: Kunio Asai (Sun Techno)
- Australia: Wolfgang Meike (Novolta)
- Austria: Hannes Heigl (Fronius International)
- Korea: Gyu-Ha Choe (Konkuk University)
- Norway: Astri Gillund (SWECO, Lysaker)
- Sweden: Bengt Perers (Lund University)

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[2] Navigant Consulting Inc 2008. The Canadian Solar Market: An Investor's Perspective. Presentation at the CANSIA 2008 conference, Toronto, Canada.

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