Performance Analysis of the PV-Storage-Diesel Hybrid Microgrid of Colville Lake, Northwest Territories, Canada Based on One Year of Monitored Data

Marc Provost, Nayeem Ninad, Dave Turcotte, Yves Poissant & Alexandre Prieur
CanmetENERGY, Natural Resources Canada

Background
- Canada’s northern remote Arctic communities are heavily dependent on diesel fuel for electricity generation
- Transportation of diesel fuel to remote locations significantly contributes to high electricity costs
- Electricity rates in the Arctic can reach 2.44 USD/kWh (rest of Canada: 0.05–0.13 USD/kWh)
- The community of Colville Lake in the Northwest Territories is the first high penetration renewable energy microgrid installed within the Canadian Arctic Circle

Objectives
- Evaluate the performance of a high penetration renewable energy system in Canada’s Arctic
- Increase utility acceptance, awareness and adoption of high penetration renewables
- Optimize the operation of renewables for reduced diesel fuel consumption and GHG emissions in arctic conditions
- Reduce risks associated with the integration of significant levels of renewables

Power System Use and Control

System Characteristics
- Battery converter is grid-forming when in operation
- PV capacity can be curtailed in steps to reduce output power

Plant
- G1 100 kW
- G2 150 kW
- G3 100 kW

Auxiliary Feeder
- Battery 200 kW/232 kWh
- Solar PV 136.5 kW

Main System Control Strategy
Few details about the control strategy are shared by the master unit controller (MUC) manufacturer. Therefore, a state flow diagram was reconstructed from the 2017 load data. This helped design a computer model of the microgrid for further performance analyses.

Community Load
- Peak load is 160 kW (73 kW avg., 30 kW min.)
- Annually, average power station consumption is ~10% of the system load

Systems
- Diesel Generators
  - One-year performance is as follows:
  - Fuel efficiency (kWh/L)
  - Uptime (h)
  - Cycles
- Battery Energy Storage System
  - Battery use is higher during the summer months when solar PV is generating power
  - Average annual converter efficiency is 98% (inverting) and 89% (rectifying)

Solar PV System
- Annual PV system yield including curtailment is 884 kWh/kWp
- PV contributes to ~50% of May’s total generation and 17% annually
- Curtailment peaks at 12% in May and June

Conclusions and Future Work
- The hybrid PV-storage-diesel system has contributed to significant reductions in diesel fuel consumption and the associated GHG emissions
- Improvements to the control strategy could help in reducing solar PV curtailment and in optimizing generator efficiency
- Future work includes project life cycle analyses through better utilization of the battery and lowering of system costs (conventional & AI control techniques)

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