PROFITABILITY AND SELF-SUFFICIENCY OF COMMUNITY RENEWABLE MICROGRIDS THROUGHOUT CHILE

Camilo Aviles, Pontificia Universidad Católica de Chile, Ph: +56 9 8341 9434, E-mail: Cam.Aviles@gmail.com
Sebastian Oliva H., Universidad Tecnológica Metropolitana, Departamento de Electricidad, Ph:+56957029312, E-mail: s.olivah@utem.cl
David Watts, Pontificia Universidad Católica de Chile, Ph: +56 9 7608 5599, E-mail: dwatts@ing.puc.cl

Overview

Microgrids (MG) connected to the grid can offer great benefits to electricity systems by improving the security of supply with clean renewable sources. Unlocking these benefits requires profitable business models that are able to drive deployment. Community energy projects could be an area with significant opportunities here. In this work, we evaluate the profitability and self-sufficiency of optimally designed community MGs in a net billing context. This is done for seventeen different geographical locations in Chile which offer a vast diversity of renewable resources and electricity tariffs. We model the optimal sizing and energy management of the MGs by minimizing the total community electricity costs. MGs can potentially be comprised by solar PV, wind and diesel generation, together with battery storage and demand response resources. We find significant levels of self-sufficiency based on solar and wind sources across the country. The community business model offer good payback periods showing that MGs are effective at reducing the community electricity bill. We therefore recommend the further promotion of community energy arrangements in order to improve the current low uptake of distributed generation in Chile.

Methods

A detailed optimization model is used to obtain the optimal sizing and energy management of a residential community microgrid. From it, we estimate the investment payback period and the achieved level of self-sufficiency throughout Chile. Detail about the business and microgrid models is provided as follows.

Community microgrid under net billing

With net billing arrangements, the residential community with a MG first self-consumes their generation (behind the community meter) and any excess of generation is exported to the grid. Hence, the community reduces its electricity bill based on the avoided electricity tariff. In this study, tariffs include an energy volumetric charge in $/kWh and a peak demand charge in $/kW/month. The community also get paid a feed-in tariff for their exports to the grid that under net billing represents only the wholesale energy value of generation (Oliva H, 2018).

Modelling the generation mix of the microgrids

In this work, MGs can be comprised by a mix of solar PV, wind and diesel generation, and also batteries to exercise energy cost arbitrage and demand response for shifting energy usage when convenient. Solar PV generation is modelled considering hourly global horizontal irradiance and module efficiency data, and the area of the PV array. Wind generation is modelled based on hourly wind speed measurements for 24 typical days. We use the equation to transform wind speed into wind generation considering the 'Endurance-50kW' wind turbine. The diesel generator model corresponds to a 'Cummins-C55D5', where the diesel-fuel performance depends on load levels. Its fuel consumption ratio is obtained from the manufacturer's datasheet. Demand response is modelled considering a maximum shiftable demand of 20% (most commonly used for residential applications) and a load-shifting price of 0.23 US$/kWh. Batteries are modelled considering the technical components of a 'Tesla-Powerpack'.

A bilevel model for optimal sizing and energy management

We build a bilevel optimization model to obtain the best sizing of the different MG components and their operation. Bilevel models deconstruct the MG planning problem into an upper-investment problem and lower-operational problem (also known as energy management) (Wang and Huang, 2015). The investment problem is a long-term optimization that finds the ideal combination, design and sizing of generation to meet future electricity demand at minimum cost. The operation problem deals mainly with the optimal MG planning over the short term. It determines the optimal generation 'unit commitment' and economic dispatch.

The case study

The microgrid projects are evaluated for seventeen diverse geographical locations in Chile. Chile is uniquely suited for our purposes due to its diverse geographic, climatic and electricity tariff conditions, which can be extrapolated to inform similar pursuits on an international level. Radiation and wind speed data are obtained from the Chilean 'Explorador' databases (Ministerio de Energia, 2016). Electricity tariffs vary widely for the different locations and are obtained from the corresponding utility tariff reports. The community electricity bill include an energy volumetric charge and a peak demand charge. We use hourly community electricity consumption data which reaches 273 MWh/year and a peak demand of 69 kW. Investment costs used are US$1300/kW for PV, US$2650/kW for wind, US$300/kVA for diesel and US$300/kWh for the batteries.

Results

Fig. 1 shows a representation of the input data, the MG generation mix and energy management for 3 diverse selected locations and the investment payback periods throughout Chile.

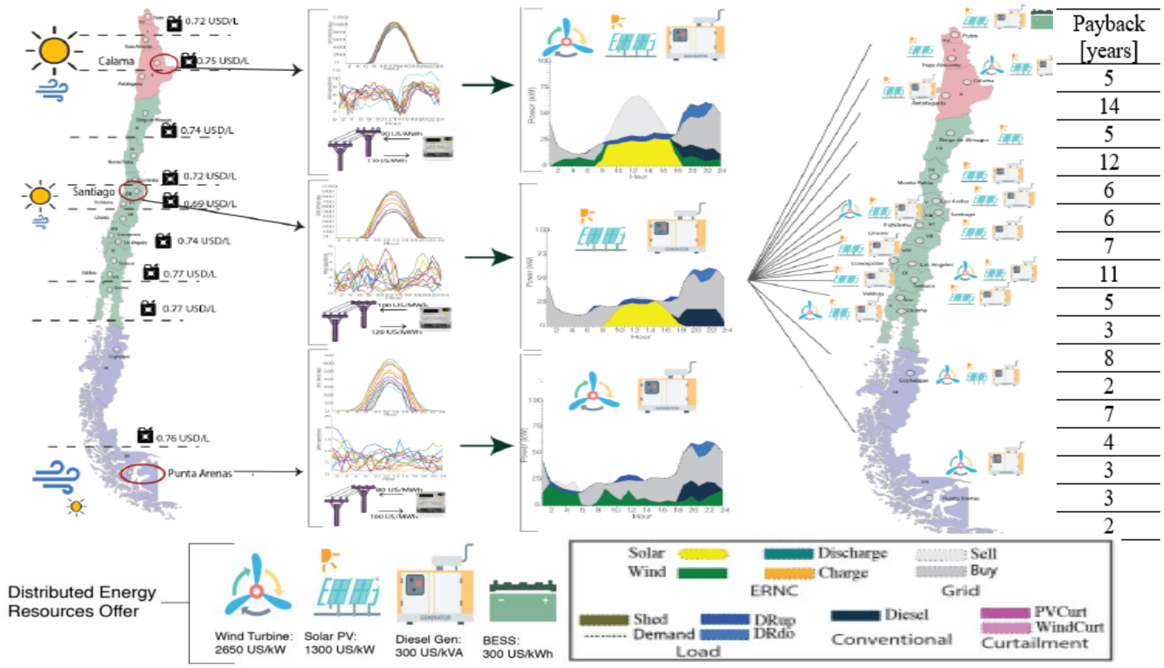

Fig. 1. Inputs, generation mix and energy management, and investment payback periods of community renewable microgrids in Chile.

Fig. 1 shows significant levels of self-sufficiency based on renewable sources, economically viable in numerous locations in Chile. Solar dominates in the north while wind does it in the south. The community business model offers good payback periods which shows that MGs are effective at reducing the electricity bill, especially the peak demand part of the bill. Wind, diesel and demand response are those that generally contribute to shave the community peak demand. Batteries are still expensive to be part of the MG generation mix. We also find better returns and self-sufficiency levels in the south of Chile due to the presence of high electricity tariffs driven by low rural population density. All these are positive outcomes for the potential uptake of community renewable microgrids in Chile.

As a consequence, we recommend the promotion of more community energy arrangements. Work is required to simplify the administrative process and improve the value of exports to the grid. These exports are still charged with the toll of the whole transmission and distribution infrastructure. However, exports most likely utilize only the low voltage grid. This, together with the addition of peak demand charges to community residential bills, can potentially assist to increase the uptake of renewable microgrids in Chile.

Conclusions

- Significant levels of self-sufficiency achieved based on renewable sources in numerous locations.
- Grid-connected community microgrids are economically viable in most locations in Chile.
- Need to improve regulation to facilitate the implementation of community microgrid projects.

References

Oliva H, S., 2018. Assessing the growth of residential PV exports with energy efficiency and the opportunity for local generation network credits. Renewable Energy 121, 451-459.

Wang H, Huang J. 2015. Joint Investment and Operation of Microgrid. IEEE Trans Smart Grid 2015:1–13. doi:10.1109/TSG.2015.2501818.

Ministerio de Energía, 2018. Chile U de. Explorador solar para Autoconsumo. Manual del usuario. 2016. http://www.minenergia.cl/exploradorsolar/