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ENERGY AUTONOMY AND MICROGRIDS IN REMOTE COMMUNITIES

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SUMMARY

For the past century, remote communities have been relying on fossil fuel to provide them reliable (as much as possible) electricity. This was mainly due to the fact that diesel power plants were the most reliable and economical way to produce electricity at the time. However, the tables are turning, and the era of renewable energy has already begun. This means that cheap, reliable and efficient renewable solutions are becoming mainstream and are now a viable solution to replace existing diesel power plants, even in the most remote locations of the planet.

Renewable energy production systems such as wind, solar or hydrokinetic, unfortunately come with a major drawback when it comes to the consistency of their power output. Because they are dependent on energy sources that are usually weather dependant, these can't be used to supply baseload power generation. These renewable sources need to be coupled with a consistent and reliable energy source to stabilize their system. Luckily, the advances in battery technology in the past few years have rendered the use of Battery Energy Storage Systems (BESS) affordable in many cases to be used as baseload coupled with renewable energies.

This is where the microgrid comes into play. In recent projects with remote communities, we have demonstrated that renewable energies could efficiently replace diesel power plants in an efficient and cost-effective way. Depending on the communities' locations and available resources, multiple energy sources can be used to ensure a year-round energy production from renewable sources. With the control systems that are becoming available on the market, and the growing interest from community members to participate in behind-the-meter initiatives such as load management and Distributed Energy Resources (DER), it is now possible to have a complete microgrid that can be fossil fuel free and bring energy autonomy to remote communities.

It is important to emphasis on that last point, where the transition from fossil fuel to renewable energy brings autonomy to the communities. Being able to be self-sufficient for their energy generation. is normally a project that will bring together community members. This is why it is important that they actively participate in all stages of the project to make the project a success in the long run.

On the technical side, in our latest remote community's project, the approach that was taken was to first integrate a modest amount of renewable intermittent energy sources to evaluate its impact on the grid. This allowed the community and the power plant operators to gather important information on the integration of such system and get accustomed to renewable energy sources. Once phase 1 was completed, a second phase to finalize the microgrid by significantly increasing the renewable energy resources and adding a BESS to the community was started. With a sufficient amount of renewable energy and the proper BESS sizing, the main power source for the system can be shifted from the diesel generators to the BESS and renewable resources. In this particular case, the existing diesel generators are kept in place to act as backup power if required.

KEYWORDS

Microgrids, remote-communities, economic analysis, Distributed generation integration, energy transition

Current situation in Canada

Canada is a vast nation which is blessed with having one of the highest percentages of renewable energy generation in the world. This access to renewable energy is however unfairly distributed as it will mostly be available in the provinces of Québec, Manitoba, and British Columbia. Although solar and wind projects are becoming more and more prevalent in Canada, fossil generation remains important. This is especially true in Canada's numerous and geographically dispersed remote communities. According to a report by Natural Resources Canada, (Canada, 2011), there are currently 277 remote community sites in Canada for a population of almost 200,000 residents. These communites are widely spread across Canada whether in Arctic, sub-arctic, islands and mountainous conditions where the current provincial grids cannot reach for economic and technical reasons.

Historically, these locations were supplied using fossil fuels, usally diesel or bunker oil. Some were lucky enough to be supplied locally by hydro-electric dams, but these villages were the exception rather than the rule. Figure 1, shows the diversity of remote communites across Canada.

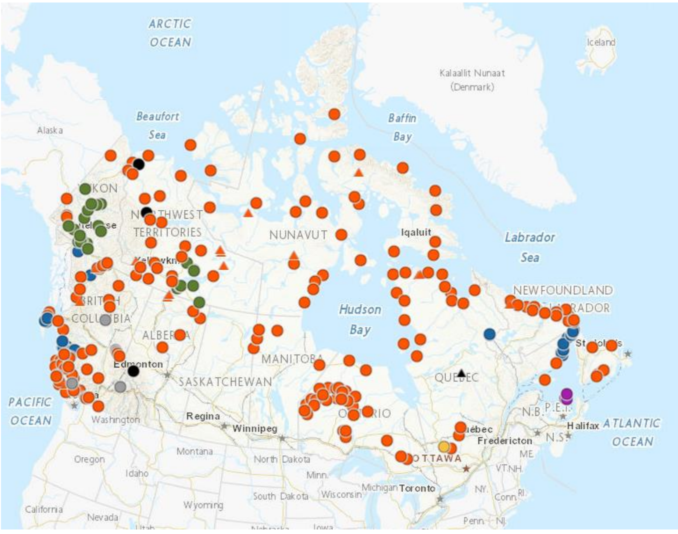

Figure 1: Location of remote communities in Canada

As Canada has ambitious goal of a 30% reduction in green house gas (GHG) emissions below the 2005 levels by 2030, several strategies need to be implemented. One on which would be to reduce the reliance of remote communities to diesel and fossil fuels and increase their energy autonomy. After all, these communities are already microgrids; greening them is a step in the right direction.

Environment and autonomy are obviously important drivers; however, economics always drives the decision. According to Lazard (Lazard, 2021), in its annual cost of energy analysis, levalized cost of energy has gone from \$359/MWh in 2009 to around \$37 in 2020. This represents a 90% reduction in costs in just about a decade. Meanwhile costs for traditional fuel souces have remained stable at \$60 to 120\$/MWh. Meanwhile, still according to Lazard, the cost of storage has also reduced greatly to about \$250/kW-year for a size relative to a remote community. These economic imperatives have caused the perfect storm to allow for a conversion of such networks.

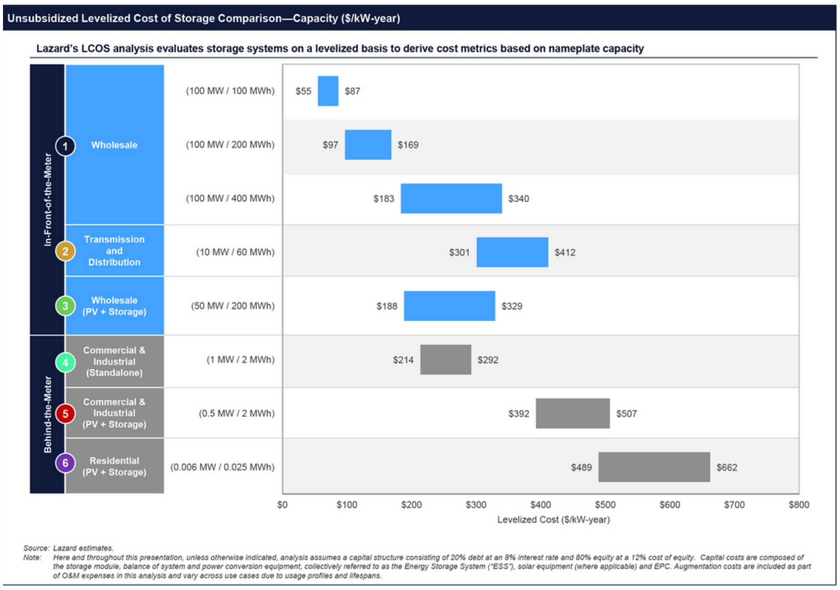

Figure 2: Lazard - Cost of storage

When looking at remote communities, it is important to note that except for one very large network, the Magdalen Islands, which has an installed capacity of 67MW, the great majority of such systems will have an installed capacity below 5MW. However, to optimize the GHG reduction, a conversion of heating systems from oil to electricity is to be considered, which could easily increase the energy demands by over 50% in each of the communities.

Building microgrids

As mentioned previously, economics now make converting such microgrids to renewable energy, something of a possibility. However, reality tends to be much more complex than an economic analysis. Reaching such destinations can be arduous, construction equipment scarce, and reliability must be flawless considering, risk on the population due to a prolonged outage as well as the time and costs associated with repairs in such remote areas. This is especially true with the addition of new technologies with operators and onsite personnel not being qualified right away to operate and maintain such equipment.

Step 1 – Energy Requirements

In building a microgrid, the first step is to understand what are the energy requirements within the community. The planner must make sure to understand what the load curve and the peak looks like, as well as what will be the requirements in the mid term future. As such, the planner may need to consider the electric conversion which may happen as cheaper and greener electricity becomes available. The energy requirements should cover 8760 hours within the year to be optimized.

This will become the base case for the planner. This base case remains one which will need to be optimized.

Step 2 – Waste is evil

In any electrical network, energy is wasted in all sorts of ways, overheating of some buildings, lighting with non energy efficient bulbs, etc. As we are entering a phase where every electron count, the planner must work in tandem with the community in order to find and reduce wasted energy. As such, the planner and the community must look at every building within the community and see if and how it can be optimized with behind the meter options. As such, to avoid coincident peaking and sudden drops in demand, the planner must look at the community as a living ecosystem of individual parts. The system being the sum of its parts, every part must work in harmony with the others. Solutions such as lighting control, better insulation, smart thermostat and water heating control as well as motor controls must be implemented. However, unlike in a regular grid, where individual savings are more important than grid management, in this case, the utility and the community must optimize the load for the common good.

As construction equipment and specialized labour costs can be quite high in such communities, simple behind the meter solutions, which may not be economical in other jurisdictions, become very cost competitive in remote communities as they can be deployed by local staff without the need for outside help. These solutions will help minimize the wasted energy and help optimize the grid.

Once a plan to “reduce waste” is put into place, the planner now has a second scenario allowing him to adjust his base case.

Step 3 – IT/OT infrastructure

The planner must understand what IT/OT communication infrastructure he as at his disposal. Should the planner be lucky, he may find a communication network with high bandwidth and low latency, however, this is more the exception than the rule. As such, in most of these instances, the telecom networks may be based on satellite communications and be expensive and slow. As such, the command-and-control schemes need to take these limitations into account.

As such, to avoid ballooning of costs, the planner must maximize local communication and infrastructure and send to the cloud only what is required for further analysis. This may lead to a microgrid which may have less advanced functionalities; however, it will allow for the system a maximized level of resiliency should communications be unavailable.

In such a difficult environment it is always required to have a simplified communications path which will allow all components to communicate through a local Scada system as simply as possible. As decisions are to be taken locally and by individual components with respect to pre-programmed schemes of operation, the communication system can be as simple as an RF point or the use of the local public infrastructure. Data for analysis, which is not mission critical will be percolated within the system when telecommunications allow for it, and on another channel than any mission critical information.

The IT/OT infrastructure must also account for behind the meter appliances. As such, these appliances may be on an open or a closed loop communication system. From which the controller may or may not see their current state of how it is functioning. The local microgrid controller must be configured in such a way where commands must be issued and assumptions must be made should communications fail, even locally. This means, that the microgrid controller must at all moments look at the aggregated load, voltage, and generation capacity as well as schedule to be able to infer whether a command has been responded to or not should a confirmation be unavailable. At all times, the microgrid controller must protect itself and the grid by making safe decisions for the grid and the community. This means that some efficiencies may be lost, however, considering the complexity of operating such systems, simpler is better.

Step 4 – Setting the master

As the planner looks at the IT/OT infrastructure, he must also question himself what appliance will be set as master and which appliances will be set as "slaves". As such, this master/slave approach will allow to ensure a black start capability as well as ensuring a certain hierarchy in what gets dispatched and when.

As such, should the planner want to avoid the use of diesel gensets, he may decide to set the Battery Energy Storage System as the master of the grid. As such, the microgrid controller will be directly connected to the BESS, allowing for the BESS to set the initial frequency as well as act as a regulating factor within the microgrid. The advantage of such a scheme is that the diesel gensets need not to be continuously running, thus reducing greatly the green house gases emitted and the use of oil. However, the planner must ensure there is always remaining energy in the batteries such that a black start can take place. Also, as batteries tend to be somewhat less reliable than gensets, this strategy may lead to blackouts should the gensets not be able to take over.

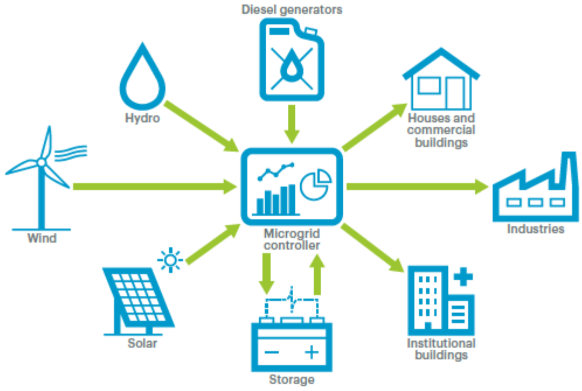

Figure 3: Conceptual microgrid

The planner may also decide to use the gensets as master. This strategy has the advantage of reducing any risks on operations; however, it will become extremely difficult to stop the gensets should enough energy be produced on the grid. Both these cases have their trade-offs; as such, there is no correct answer to this question; however, the planner should consider in his analysis what is at stake in case of issues and is the microgrid controller capable without human intervention of modifying its command-and-control scheme. In Figure 3, a conceptual view of the microgrid is presented. Although the microgrid controller is central, and it does act like the brain of the network, the planner must never forget who is the real boss, and that is, the appliance which will send the frequency signal.

Step 5 – Making it all work together

Making it work together is where the rubber hits the road. The planner has run his simulations, optimized its energy flows coming from different sources of generation, the diesel gensets and the battery storage. The local and remote Scada systems have been selected. Telecommunications have been optimized and everything works well on paper.

To make it all work together, the planner must make sure that his testing sequence will consider all different required safety and operational standards are followed, such as :

- IEEE 2030.3,
- IEEE 2030.5,
- IEEE 2030.7,
- IEEE 2030.8,
- IEEE 2030.9,
- IEC TS 62898,

The testing must be done in such a way where all operational modes and corner cases are tested while ensuring that the service continuity is not affected, therefore avoiding issues with the community. Local load banks may be used in order to simulate reality.

When integrating microgrids, especially in remote communities, old diesel systems are usually kept in place as backup energy sources. Once the microgrid is properly tested on its own, transition tests are important to be completed between the existing systems and the new microgrid. This is important to ensure that switching between the systems will be seamless.

Step 6 – How it worked together

Once all the proper design, construction and integration steps have been followed, that the community has been involved all along the process, and the system is finally ready to go, the result is community project that brings renewable energy, new technologies and innovation all together for the benefits of everyone.

In remote communities where diesel generators and fuel tanks were part of the landscape, people have been immediately pleased with the results. Switching to renewable energies has brought them closer to newer technologies, as well as improving their daily lives. The quietness of PV and battery storage compared to diesel generators was one of the major upside but taking part in the energy transition has also brought pride to everyone involved in the project.

In a more complex microgrid project like the Lac-Mégantic microgrid, the integration of multiple new technologies and innovation with existing distribution systems, buildings and infrastructures, the meticulous planning that was done early in the project between the community, the utility and the design team played a key role in the project’s success. This project also allowed the utility to familiarize with microgrids in a “controlled environment” before deploying multiple systems for the remote communities on their territory.

As it is the case in most of the projects, planning is the key in microgrid projects. Defining the energy requirements and identifying opportunities to improve energy efficiency will allow for an optimize microgrid with the right choice of energy sources and storage. Identifying the right IT/OT infrastructure, and designing the right control system will allow for a smooth integration and operation of all individuals systems.

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