FUEL CELL SYSTEMS FOR REMOTE COMMUNITIES: THE FIRST STEP TOWARDS A RENEWABLE-HYDROGEN ECONOMY IN CANADA

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This paper describes the technical feasibility of a stand-alone, renewable energy, regenerative fuel cell system, evaluates the sustainability of the proposed system for off-grid communities, reviews current policies and proposes a framework to support implementation.

This paper has been edited for length. To view the original, please visit www.peo.on.ca/index.php/ci_id/29078/la_id/1.htm.

IN CANADA, there are 292 remote off-grid communities with a total population of 194,281. Most off-grid communities are Aboriginal. And most rely on diesel-fuel power plants. The rest use alternative energy sources with diesel generators as a back-up system.

Renewable energy, such as hydro, wind and solar energy, is an attractive alternative to diesel generators and power plants. However, its intermittent nature leads to a requirement for a reliable energy storage system.

A viable storage solution is a discrete, regenerative fuel cell system. Renewable energy sources are preferentially used to meet the load demand. In times of excess renewable energy, electricity can be converted through water electrolysis to hydrogen–now the system's energy carrier–which is then stored in a compressed tank. When the available, renewable energy sources are insufficient to supply the load demand, a fuel cell, hydrogen turbine or combustion engine converts the stored hydrogen back to water, producing electricity.

A transient study was performed through Transient System Simulation Tool (TRNSYS 17) to simulate a system that could cover the residential load for one year in a community of 10 dwellings and a total peak load demand of 60kW.

During the day (8:00 a.m. to 4:00 p.m.), when the power from renewable energy sources exceeded the power required, the electrolyser operated. The fuel cell switched on from 4:00 p.m. to 8:00 a.m. when there was a deficit in the available renewable energy. The power from the fuel cell matched the load demand.

Over the one-year simulation, an average system efficiency of 23 per cent and an average hydrogen loop efficiency of 32 per cent were obtained for a renewable-regenerative fuel cell system made up of electrolyser stacks with a total power rating of 75kW, and fuel cell stacks with a total power rating of 60kW. This represents a significant loss of efficiency compared to competing technologies, such as diesel generators and battery systems.

However, for a stand-alone, renewable system, reliability and dynamic response of the back-up system are more important than efficiency. To better match the input and output requirements of the components, improve efficiency and ensure autonomy, key parameters to take into consideration in designing the system are load profile, control strategy, climate and available renewable energy.

SUSTAINABILITY OF PROPOSED SYSTEM

Environmental

The only viable competitor to a hydrogen energy storage system is a diesel generator. In the cold climate of off-grid Canadian communities, lead acid batteries tend to freeze and their efficiency is reduced with decreasing temperature. Their end-of-life disposal and relatively long charging time are further concerns. Diesel generators produce considerable greenhouse gas emissions, smog and air contaminants during operation, which contributes to global warming. Fuel spills and leaks can contaminate the soil and groundwater resources.

A regenerative fuel cell system is pollution free with water and waste heat being its only outputs. Waste heat from the fuel cell system can be used for heating needs in a combined heat and power subsystem, which improves the system's overall efficiency.

Emissions resulting from transporting diesel by road or air to remote locations would also be eliminated. Because hydrogen fuel would be generated on site, energy independence would result and risks to the ecosystem would be reduced.

Because surplus hydrogen could be used to fuel automobiles in remote communities, the replacement of fossil fuel vehicles would further reduce pollution and decrease dependence on fuel imports.

The water requirements of an electrolytic process could be a potential impediment in some off-grid locations where water is a scarce resource. However, water would be produced by the fuel cell with the water balance dependent on the available renewable energy and load profile. Accordingly, this should be factored into an environmental impact assessment of a renewable hydrogen system. However, the water requirement is quite low: 250-560 litres of water for each MWh of hydrogen produced.

Economic

Without subsidies, the cost of running diesel generators is higher than a renewable hydrogen storage system. In Ontario, most diesel is transported by plane at a high cost. The fluctuating market price of diesel, combined with its high demand in colder, remote locations further contributes to a high electricity rate for consumers unless subsidized by government.

Economic development is also hampered by high energy costs. Annual operating cost savings of over $900,000 from a renewable hydrogen storage system were obtained in a study for a hypothetical remote community (www.ballard.com/files/PDF/Distributed_Generation/Fuel_Cells_for_Remote_Communities_-_White_Paper_-_Apr_2012.pdf). However, the initial capital costs of installation are a major drawback that limits investment, especially given the low round-trip efficiency of the system.

According to Chauhan et al., such integrated renewable hydrogen systems should have a total load demand that exceeds 120kW for economic feasibility (http://publications.gc.ca/collections/collection_2011/schl-cmhc/nh18-1-2/NH18-1-2-133-2005-eng.pdf). In remote locations, this investment would be worthwhile as it would create a sustainable, clean and reliable energy system. Reducing energy costs and creating jobs and services around a self-sufficient, micro-hydrogen community could give an economic impetus and boost development.

Surplus hydrogen produced could lead to a demand for fuel cell vehicles and hydrogen fueling stations. By replicating this model in neighbouring rural areas, urban regions could become later adopters once the technology was more mature and affordable. This new market would not only benefit Canadian companies, such as Ballard Systems and Hydrogenics, which are already established leaders at the world level, but would also encourage start-ups in electrolyser and fuel cell technologies.

Social

Remote Aboriginal communities suffer from complex social issues compared to the non-Aboriginal Canadian population: poorer health, lower level of education, inadequate housing, lower income, higher unemployment level, high incarceration level and higher death rate among youth due to suicide and unintentional injuries. Installing a renewable hydrogen energy system could alleviate some of these problems by creating jobs, providing a sense of sustainability, fostering community pride and encouraging entrepreneurship.

Improved air quality could reduce the incidence of asthma and bronchitis, which is higher in these populations than the Canadian average. Having power supplies close to the home and reduced vulnerability to power disruptions could lead to a better quality of life, as would suitably heated infrastructure, such as schools and community centres.

A discrete regenerative fuel cell system operates silently, which is drastically different than noisy diesel generators that disturb the usually quiet surroundings of remote communities. First Nations have traditions in which nature plays an important role. Integrating these values with the implementation of renewable infrastructure can promote acceptance. Major social challenges to this type of energy project include lack of technical skills and support, apprehension in co-operating with non-Aboriginal companies, lack of funding, etc.

EXISTING ENERGY POLICIES IN ONTARIO AND CANADA

Canada's national energy policies have been shaped by various agreements, programs and commissions. However, energy resources are under the jurisdiction of provincial governments and each has its own acts and policies. This lack of harmonization can lead to divergence from the federal vision. At the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) 2014 meeting in Oslo, Norway, the Canadian steering committee acknowledged the absence of a dedicated fund and mechanism for a hydrogen and fuel cell economy.

For the hydrogen and fuel cell industry, there are implications that cut across the mandates of nearly all federal ministries. The absence of a Canadian energy policy comparable to the US Department of Energy (DOE) Hydrogen and Fuel Cells Program or EU Blueprint 2020 could be an impediment to coordinated and coherent actions toward common national policies.

Although the federal government released Canadian Fuel Cell Commercialization Roadmaps in 2003 and 2008 to lay out strategies for achieving commercial viability and mass market success, this has not brought a more focused plan of action. For instance, many of the roadmap recommendations were missing from the Ontario Fuel Cell Innovation Program.

The principal stakeholders in Canada's hydrogen and fuel cell sector are represented by the Canadian Hydrogen and Fuel Cell Association, a national, non-profit organization that collaborates with the Canadian government and PricewaterhouseCoopers LLP to publish an annual industry profile. The findings from the 2013 report identified lack of funding as the primary challenge faced by the fuel cell industry. Since 2001, there has been a considerable drop in R&D funding and people employed in the industry despite an increase in revenue. In 2012, the Canadian government contributed only 12 per cent of funding for R&D activities and 13 per cent for demonstration projects.

The National Research Council and the Natural Sciences and Engineering Research Council fund several industrial research chairs in Ontario, both in renewable energy development and fuel cell technologies. There are many other government-funded programs in other provinces, leading to a lack of interaction among research groups sharing quasi-similar objectives. In 2012, academics were involved in only three of 59 global demonstration projects.

The ecoENERGY for Aboriginal and Northern Communities 2011-2016 (EANCP) program provides around $15 million dollars for renewable energy projects ($250,000/project) and sustainable integration of buildings ($100,000/project) in Aboriginal and northern communities. There are other sources of federal funding. Provincially, the Ontario Power Authority's Aboriginal Renewable Energy Fund may fund up to 50 per cent of expenditures up to $500,000 for large projects and $100,000 for small projects. The M'Chigeeng First Nation wind turbine project is the first successfully commissioned project. A water power project at Pic Mobert and a wind project at Henvey Inlet also benefitted from this fund. However, an energy storage solution does not seem to have been included in the projects.

As for regulations, a Canadian Hydrogen Installation Code CAN/BNQ 1784-000 has been developed by the Bureau de Normalisation du Québec (BNQ) and approved by the Standards Council of Canada to cover installation requirements for equipment for hydrogen generation and use, hydrogen storage containers, piping systems and related accessories, with certain exceptions (www.scc.ca/en/standards/work-programs/bnq/canadian-hydrogen-installation-code). Internationally, the International Organization for Standardization (ISO) is developing ISO/TC 197-Hydrogen Technologies.

AN ALTERNATIVE POLICY FRAMEWORK TO SUPPORT IMPLEMENTATION

Federal energy policy

A national energy strategy integrating fuel cell and hydrogen technologies is required to provide a clear action plan and specific goals with timelines. This vision can then be used to guide the development of provincial policies. A harmonized approach will ensure coherence among the different Canadian stakeholders across the provinces, enabling the formation of bigger networks, collaborations and partnerships at the research, commercial and industrial levels. For instance, the European Renewable Directive sets targets and oversees the action plans of each state. The US DOE has a fuel cells technologies office that provides centralized support for developing and deploying these technologies.

There is also a need to revamp the National Energy Board to include experts with diverse energy backgrounds to represent the interests of all energy industry stakeholders. Due to a hydrocarbon-based energy strategy in western Canada, hydro-nuclear in the east, and the failure of the National Energy Program, there is a need for bold federal political actions to reunite and coordinate efforts.

Education and awareness

The Hindenburg disaster in 1937 has shaped the public perception of hydrogen as a dangerous substance, but hydrogen is less destructive to its immediate surroundings than gasoline or diesel due to its low density and propensity to combust in an upward direction rather than circumferentially. However, hydrogen is flammable and explosive. It is also odourless and combusts with an invisible flame, making leak detection challenging.

To promote acceptance of hydrogen as safe, efficient and environmentally friendly, educational activities geared to the audience should be conducted to raise awareness of hydrogen's potential. For Aboriginal audiences, successful demonstration projects led by the communities themselves–such as the projects led by the Piikani Nation in Alberta and M'Chigeeng in Ontario–could be showcased. When promoting renewables as an alternative energy solution, hydrogen energy solutions should be mentioned.

Skills and capabilities

Most personnel skilled in fuel cells and electrolysers are from graduate research programs in engineering. To enable an expansion of the industry, an enlarged, diversified workforce with different levels of technical knowledge and expertise is required. Governments should encourage postsecondary institutions to include a fuel cells technology module as an elective in undergraduate engineering curricula, especially in the chemical, mechanical, electrical and material programs, to promote this field. Co-op and internships in small and start-up companies could be subsidized by the government, which would give students opportunities to receive practical training and provide technical support to companies.

These measures would help ensure Canada becomes a centre of excellence in hydrogen and fuel cell education, paving the way to more research breakthroughs and preventing researchers moving to countries with stronger support for hydrogen. Despite being a pioneer and world leader in the fuel cell industry, Canada is being surpassed by the US, Japan, European Union and China.

Codes, standards and regulations

The Canadian Hydrogen Installation Code CAN/BNQ 1784-000 is not sufficient to ensure regulatory compliance. It costs around $100 to $300 to access the code, the last available update is for 2007 and BNQ offers only a French version of its website.

To encourage start-up Canadian companies and enable international sales of products and technology, barriers to accessing these regulations and obtaining site permits and licences should be removed.

To maintain leadership in developing quality assurance for hydrogen and fuel cell technology, further tools to ensure consumer and industrial safety must be implemented. For instance, the Pacific Northwest National Laboratory funded by the US DOE recently released a National Hydrogen and Fuel Cell Emergency Response Training Resource, which provides free first responder community training materials.

Financial incentives and funding

Although funding programs are available for Aboriginal communities, the paperwork and administration can be so complicated that it deters the pursuit of projects. A dedicated support unit within concerned ministries could conduct workshops in remote regions and assist in filling out applications.

Because system efficiency is location-specific, a solution in one community will not fit another. Scholarships could be made available for fourth-year undergraduate engineering projects and masters-level graduate students who want to get involved in renewable-hydrogen projects in remote communities. By working under the supervision of licensed engineers, the involvement of graduate students could help bring down consulting costs. By collaborating with researchers in the social and environmental sciences, the benefits of renewable and hydrogen solutions could be compared to competing fossil fuel technologies. Government funding would then not only promote fundamental research to advance hydrogen technology, but also support demonstration projects.

Apart from increasing funding for R&D, overhauling the rules and mechanisms associated with tax incentives, loans, subsidies and risk financing support would encourage entrepreneurs. Government grants should be provided to fuel cell companies to encourage them to test the new technologies in remote and off-grid regions. However, care must be taken to ensure renewable-regenerative fuel cell storage energy system projects do not just remain demonstration projects.

The Canadian Fuel Cell Commercialization Roadmap published in 2008 predicted fuel cell penetration would start off with portable electronic devices (2009-2013), then residential co-gen (2012-2017) and finally fuel cell vehicles (2015-2017). This is clearly not happening as forecasted. After nearly seven years, this roadmap needs to be redefined, notably by placing renewable-hydrogen energy storage systems in remote communities at the forefront of near-term applications.

CONCLUSION

With nuclear reactors reaching their end of life and the strong influence of the oil industry on the Canadian economy, this is an interesting time to create a unified federal energy vision. It is essential there is a political environment conducive to this shift in energy priorities and subsidy allocations.

The classic chicken-and-egg scenario for fuel cell vehicles and hydrogen fuel stations does not exist for the near-term application of renewable-hydrogen energy storage solutions. Instead of implementing renewable-hydrogen systems in remote communities as demonstrations, such projects should be the first stage of hydrogen infrastructure development.

A distributed generation future is feasible only once a viable energy storage solution becomes mainstream. For wider adoption, research and development support is required to improve the cost, efficiency and durability of the system.

The vision of the Idle No More movement (www.idlenomore.ca/vision) calls for indigenous people to be active actors in more sustainable practices. By leading sustainable energy initiatives, Aboriginal people could be more engaged, which might have a positive impact on the socio-economic issues in remote communities. On a grander scale, this could gradually steer Canada away from the fossil fuel industry into a renewable-hydrogen economy future. Σ

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