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Development of Wide Area Electricity Markets and the Means to Achieve them

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SUMMARY

Accommodating the development of distributed energy resources or microgrids is a challenge to conventional vertically integrated utilities. As customers install their own variable generation and battery storage, their only recourse to sell surplus electricity they might have today is to the utility. As microgrids develop, peer-to-peer trading is starting to be of interest with a blockchain transaction process. Distribution System Operators are starting up.

Variable renewable generation is dropping in price resulting in the displacement of conventional generation. Balancing the intermittency of variable generation has become one of the challenges to be faced giving rise to an Energy Imbalance Market now operating in parts of the Western Electricity Coordinating Council. Balancing markets are expected to develop but require wide area participants with interconnecting transmission to be effective.

Wide area transmission across western Canada in the form of a “macrogrid” would facilitate an Energy Imbalance Market. It would also provide economic opportunity for provincial and territorial grids to reduce their reserve generation margins over time saving money as aging generation units are retired with the grid providing reliability while minimizing the amount of replacement generation required. Transmission for a macrogrid must have a benefit/cost ratio equal to 1.0 or greater to be profitable, with profits shared by customers. The days of dumping costs of unprofitable projects on the shoulders or ratepayers and taxpayers must go.

Microgrids, regional grids and macrogrids can all be interconnected to allow trading of electricity. Each level of grid in effect becomes a market, providing best reliability for the customer, and best economic benefit.

KEYWORDS

Electric energy markets, variable generation, energy imbalance market, microgrids, macrogrids, blockchain, DC grids.

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1. INTRODUCTION

How do we develop our electric power systems to meet the rapidly changing conditions that can disrupt the way forward? The electric power system has seen more changes in the past five years than in the 100 years preceding. There are low costs of variable generation and storage, the need to reduce thermal generation, the uneconomical cost of new large hydroelectric generating stations, the evolution of distributed energy resources (also known as microgrids) and the market systems that must be put in place to meet these changes. In addition, there is the evolving electricity mobility market and its offshoot of fuel cell mobility with hydrogen for heavy transportation.

Balancing variable generation is a necessity and is this best achieved with a capacity market such as with single cycle gas turbines? At present, balancing authorities maintain the stability of their network frequency with the general practice of intermittent interchange of energy between balancing areas.

Taking into account all these developing challenges, this paper presents a broad perspective on how the way forward for the development and marketing of electricity as the new energy can be achieved.

2. THE INTERESTING DEVELOPMENT OF MICROGRIDS

The microgrid advancements are indeed a rising challenge for regional power systems to which they are connected into. Developments with this evolving power system include but are not limited to consumer owned generation and battery storage, energy management systems, consumers buying and selling energy for their overall minimum costs for energy and smart appliances. The over arching issue is the regulatory environment that is required.

The microgrid is of interest to minimize the adverse impact of local area power outages. For those that are fortunate enough to be able to remain in their homes or keep their businesses operating following either storms, fires or floods that bring down the regional grid, having access to their own microgrid power is significant. In any case, microgrids are disruptive to the way conventional utilities have been operating, particularly when customers invest in assets behind the meter because in part retail tariffs are rising and distributed generation costs are falling.

How can microgrid operation be achieved? This need requires establishing Distribution System Operators (DSOs) as better ways are sort to operate a microgrid and realize new optimization mechanisms on the local level and where applicable, interconnection to other systems [1]. This gives rise to new types of services such as peer-to-peer (P2P) trading and development of flexible services unlocking revenue streams to residences, communities and businesses as microgrids grow on an increasingly decentralized network.

3. TRANSFORMING THE MARKET OF THE MICROGRID

Transforming the market in the energy sector is not like the market places we already are familiar with such as taxis and purchase of on-line services. All involved must partner to work towards a common goal. Peer-to-peer trading of electric energy may be best accommodated at some time in the future with a blockchain based transaction service. Such a service would connect electricity producers, suppliers, consumers alike, all the while enabling previously unattainable cost reductions through a blockchain-enriched balancing service, designed to remove inefficiencies, decentralize supply and forecast demand.

Movement forward in managing electricity transactions using a blockchain approach is already being tested. The Netherlands company TenneT along with the German company Sonnen GMbH have started their first grid-stabilization pilot project, using interconnected storage systems based on IBM's blockchain technology [2]. On this continent, LO3 Energy is using blockchain in New York City as one example of its growing interest [3].

4. THE ENERGY IMBALANCE MARKET

Energy imbalance is the difference between real-time demand for electric generation compared with pre-arranged schedules. This is expressed as:

Energy Imbalance = Actual Usage or Production – Scheduled Usage or Production

Balancing Authorities (BA) maintain a load-resource balance and stability of system frequency within an area under the rules of the North American Electric Reliability Corporation (NERC). The increase in variable generation increases the challenge to maintain a balance between electricity production and demand. This may lead to curtailment of wind as an example. This is where an Energy Imbalance Market (EIM) is beneficial where the following problems can be addressed:

- Provide a purchase or selling market for accumulated imbalances within a BA
- Dispatch generation over a wide area basis within the capabilities of interconnections thereby reducing the risk of any BA running out of balancing reserves
- The Energy Imbalance Market allows transactions on a least cost basis

Where there is no EIM compared with an EIM is shown in Figure 1:

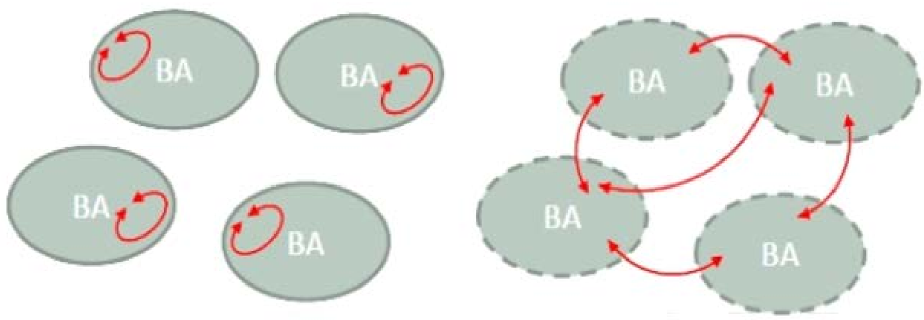

Figure 1: Balancing Authorities without and with an Energy Imbalance Market [4]

What then are the benefits of an Energy Imbalance Market? For participants, an EIM can result in:

- Decreased levels of reserve generation, meaning that as generating plant is retired in utilities in an Energy Imbalance Market, their reserves to meet peak loads can be lowered. In the western Canada provinces, reserves of firm generation are unusually high. This is evident in Alberta in 2016 where they operated with 35% firm margin (wind and solar generation excluded) [5] and 37% margin in 2017 [6]. Other western provinces are also operating or will be operating with high margins. A western Canada EIM with adequate interconnection capacity between the Balancing Authorities of the provinces will allow reserve levels of firm generation to be reduced while maintaining reliability

- There is an economic societal benefit for an Energy Imbalance Market with full, wide area participation
- The Energy Imbalance Market preserves Balancing Authority autonomy and reserve obligations
- Automated dispatch facilitates increased penetration of variable generation, resolves imbalances and avoids congestion [7]

There have been a number of concerns raised that include increased jurisdiction would result in provinces and local authorities with decreased ability to protect their consumers. There are fears start-up costs would be shifted to customers.

The Energy Imbalance Market is generally operating successfully in the Western Electricity Coordinating Council (WECC) with BC Hydro’s Powerex joining earlier this year. However, Powerex has problems with the market rules that undercut the value of its hydroelectric resources [8].

Establishing an Energy Imbalance Market in the western Canadian provinces will require evaluating what is successful with the EIM in the WECC and what is not. Rules can then be formulated that are acceptable to all provinces, utilities and jurisdictions who express an interest in participating in a western Canada EIM. An initial stage is to have a substantial wide area and profitable transmission system for an Energy Imbalance Market.

5. INCREASING INTERPROVINCIAL INTERCONNECTION CAPACITY IN THE WEST

Canada suffers from having minimal benefits of east-west trade in electricity despite the many studies promoting such. Even the 2017 Canadian Free Trade Agreement in the pertinent Annex 309 provides minimal emphasis on interprovincial trade of electricity just requiring that “*any transmission service provider operating within its territory provides all transmission customers with open and non-discriminatory access to transmission service*” [9].

However, the Canadian Academy of Engineering in their April 2016 final report “Canada’s Challenge & Opportunity” state: “*It is necessary to invest in additional high voltage interconnection capacity to benefit from increased trade of both electrical energy and dependable capacity between neighboring jurisdictions*” [10].

Of significance is the federally funded Regional Electricity Cooperation and Strategic Infrastructure (RECSI) initiative [11] nearing completion at the time of writing. The western study under the direction of the Alberta Electric System Operator (AESO) is examining east – west transmissions and markets. It does include examining the benefits of new interconnection options between the western provinces and territories including impact on operating reserves.

The Canadian Federal Government has a definite interest in RECSI and strategic electricity interties with a report by the Standing Committee on Natural Resources [12]. Recommendation 1 of this report with government concurrence stated that “*electricity interties can support provincial renewable electricity targets and help manage the variable output of some renewable electricity resources*” and provide “*opportunities to coordinate interprovincial electricity trade between low-carbon electric-dominant provinces and their neighbouring provinces*.”

One configuration in the future for interconnecting western Canada electrically and into the “macrogrid” of the US is presented in Figure 2:

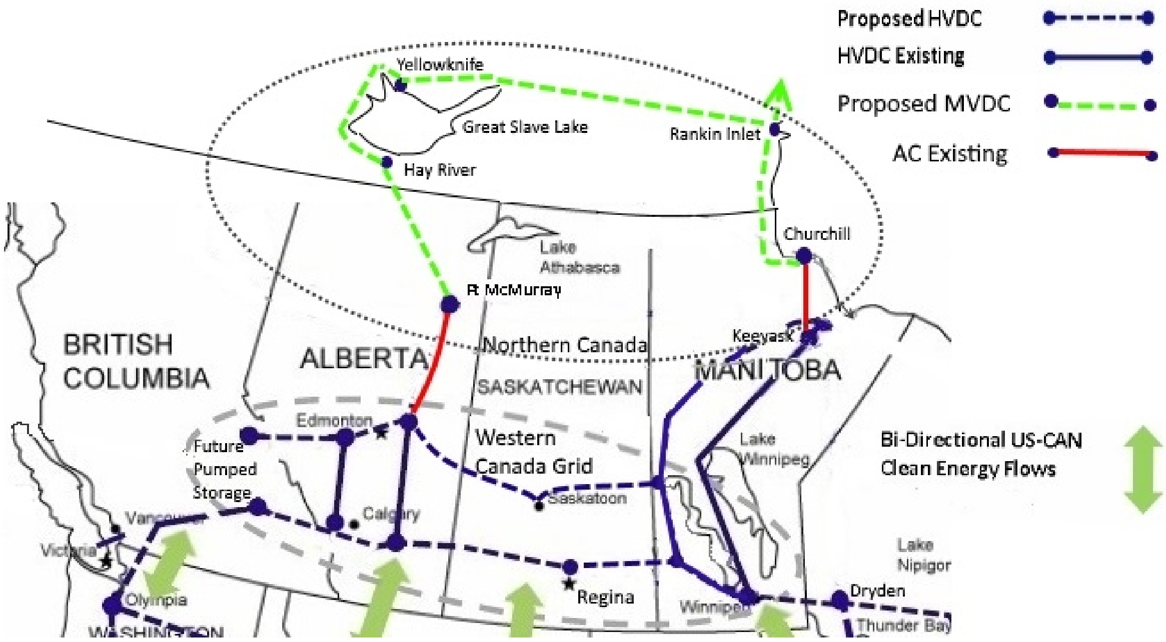

Figure 2: A possible future interconnection of western Canada with a macrogrid

In establishing a macrogrid, a most significant fact is not understood or appreciated. The transmission system should not be built on the shoulders of rate payers or tax payers. How then can it be justified? This is demonstrated by a significant study led by the National Renewable Energy Laboratory (NREL) of the US Department of Energy which also has Canadian participation. It is the Interconnection Seam Study which is a detailed examination of providing high-capacity interregional transmission that spans between the Eastern and Western Interconnections [13]. It demonstrates that high-capacity interregional transmission provides deliverability that we do not have today. The study is presently showing that under present policy conditions, a 15-year benefit/cost ratio ranges from 1.13 to 1.26.

It is very important to appreciate that any western Canada macrogrid plan must be profitable and produce a benefit/cost ratio greater than 1.0. Otherwise it is a drain on ratepayers and taxpayers who should share the benefit, not shoulder the losses. If there is value in a macrogrid, then an economic, reliability and resiliency analysis must be evaluated in order to attract investors, both private and public. The benefits of a macrogrid can come from:

- Reducing generation margin as older generating plant is retired, the some of the savings in not completely replacing them can be allocated to the construction of the macrogrid

- Although loads have generally been reducing in recent years, the inevitable transfer to electricity for mobility, both heavy and light including fuel cell-based drives will increase load again. The macrogrid will enable margins to be shared keeping new generation costs to a minimum
- An Energy Imbalance Market can be established as well as east-west diversity markets. Larger more integrated wide area electric energy markets would be established for all interconnected regional utilities
- The adverse impacts of sudden regional weather changes on solar and wind energy generation are smoothed out in a power system spanning several regions
- Hydroelectricity in Manitoba and BC and potential new pumped storage facilities [14] would be utilized as bulk energy storage, providing balancing capability and capacity to back up new variable renewable energy generators
- Greater advantage can be made of the lower cost variable generation which can be balanced with the EIM over the wide area the macrogrid offers

A performance requirement for a macrogrid is self contingency. This is the (N-1) reliability constraint that the macrogrid must conform to. The constraint is that loss of one incoming DC line must result in minimum disturbance to the underlying AC regional network. The simplest but by no means the least cost way for a macrogrid to be self contingent is to have all DC line sections comprised of two terminal DC transmission lines. The connection to an underlying AC regional network is shown in Figure 3. If HVDC 1 line fails, the macrogrid must be controlled such that HVDC 2 line immediately would limit (N-1) constrained AC/DC exchange to the lower of the two pre-event DC MW power exchanges.

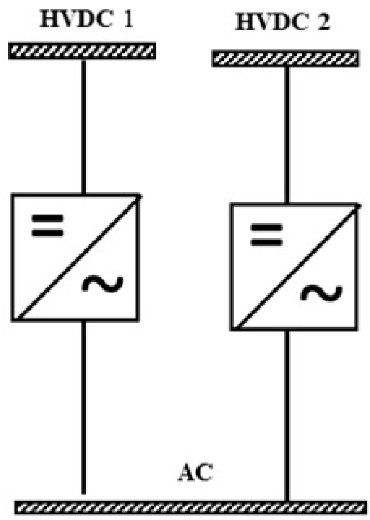

Figure 3: Achieving self contingency at the macrogrid connection to the AC network

The western Canada macrogrid of Figure 2 provides a grid path to allow rapid rescheduling of grid DC power flows in the event any macrogrid line section fails. There are lower cost means of achieving self continency than described here and in Figure 3 [15].

6. LINKING MACROGRIDS, REGIONAL GRIDS AND MICROGRIDS

The macrogrid will require an independent system operator. Its role would be to operate and manage Energy Imbalance Markets and other markets transacted between regional electric networks province to province to territory. The Alberta Balancing Pool balances the electricity requirements in Alberta and does so as an independent balancing authority under the jurisdiction of the Alberta provincial government and would still continue doing so with the macrogrid. It may choose to take advantage of the EIM and the benefits the macrogrid would offer. Other provinces and territory may choose similarly.

Electric energy markets can be integrated between local (microgrids), regional (the provinces & territories of Figure 2) and then transcontinental with an expanded macrogrid. with possibly an operator managing the western Canada markets. NERC Rules and standards will have to be developed accordingly.

Figure 5 shows conceptual levels of future markets for electricity. Connections between the three levels of microgrid, regional grid and macrogrid will provide reliability and economic opportunities through trading in electricity. Markets will range from peer-to-peer trading at the microgrid level up to wide area trading such as EIM at the macrogrid level. Electricity trading may be accomplished under a blockchain contracting process or some other alternative.

From time to time, Distribution System Operators will need to trade with the regional grid. Retaining an interconnection to the regional grid will contribute to the reliability and economic benefits for the consumers and producers in the microgrid.

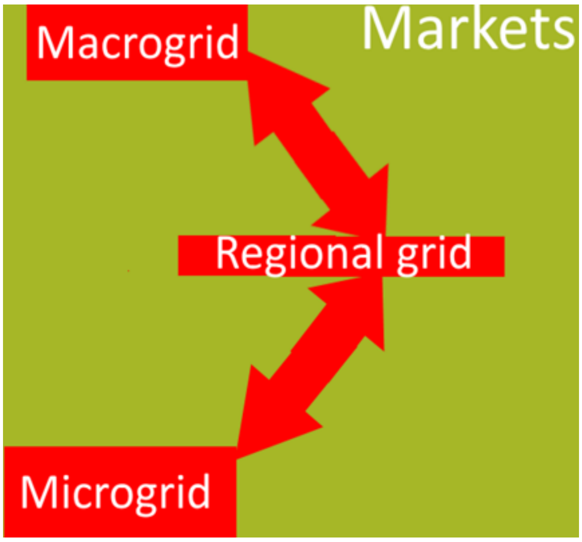

Figure 5: Levels of markets in the future electric power system

Likewise, the regional grid will be trading actively with the microgrids and the macrogrids. There is a tremendous amount of development ahead for the electric power system industry.

7. CONCLUSIONS

The electric power system is changing dramatically. The way forward is not the way we have always done it in the past. This paper presents a possible direction for the future. But it is becoming impossible to predict the future. Instead, the best way to predict the future is to create it [16]. Ultimately the lowest cost and most reliable electricity for the "New Energy" is required. With this as the objective, we move forward step by step creating an energy future that takes into account the reality of the developing circumstances around us, building our future society and its economic strength.

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