Variable Energy Resources: VERy Interesting Implications for the Western Interconnect

Variable energy resources (VERs) are growing in the Western Interconnect. To backstop the associated intermittency, the grid needs more firm energy or transmission increased. The low utilization rate of natural-gas-fired generation appears to be preferred over new transmission infrastructure. New ancillary markets may be required to mitigate reliability issues.

Amy Sopinka and Lawrence Pitt

Amy Sopinka *is a post-doctoral research fellow at the Pacific Institute for Climate Solutions in Victoria, British Columbia. She completed her Ph.D. at the University of Victoria. Her dissertation work focused on the economic and environmental effects of wind integration in the weakly interconnected Alberta and British Columbia grids. She obtained an M.A. from McGill University and a B.A. from Queen's University.*

Dr. Lawrence Pitt *earned his B.Sc. in Applied Physics and M.Sc. in Electrical Engineering from the University of Alberta and a Ph.D. in Plasma Physics from the University of Victoria. He has been involved in research and development for a variety of energy systems: laser-fusion, combustion systems and alternative fueled vehicle systems design, hydrogen systems, and grid integration of large-scale renewables. At various times, he has been a combat systems engineer in the Navy, navigated a tall ship cruising the Pacific, developed and coordinated the early years of the engineering co-op program at UVic, and served as Research Coordinator at UVic's Institute for Integrated Energy Systems (IESVic). He is currently Associate Director of the Pacific Institute for Climate Solutions.*

I. Introduction

The North American bulk power system is comprised of four interconnected regions: the Western Interconnect, the Eastern Interconnect, ERCOT, and the Quebec Interconnect. Reliability within synchronous Western Interconnect is currently overseen by the Western Electricity Coordinating Council (''the WECC''). The WECC region comprises 37 balancing authorities located across Alberta and British Columbia, known hereafter as WECC-CA, all or part of 14 U.S. states (WECC-US), and northern portion of the Baja Peninsula, Mexico (WECC-MX). The entirety of the WECC is shown in **Figure 1**.

In December 2012, the WECC Board of Directors voted to allow the bifurcation of the existing structure into two separate bodies: a reliability coordination company (RCCo) and the regional entity (RE). In part, this separation is the result of conflicting goals within the single organization; members may be

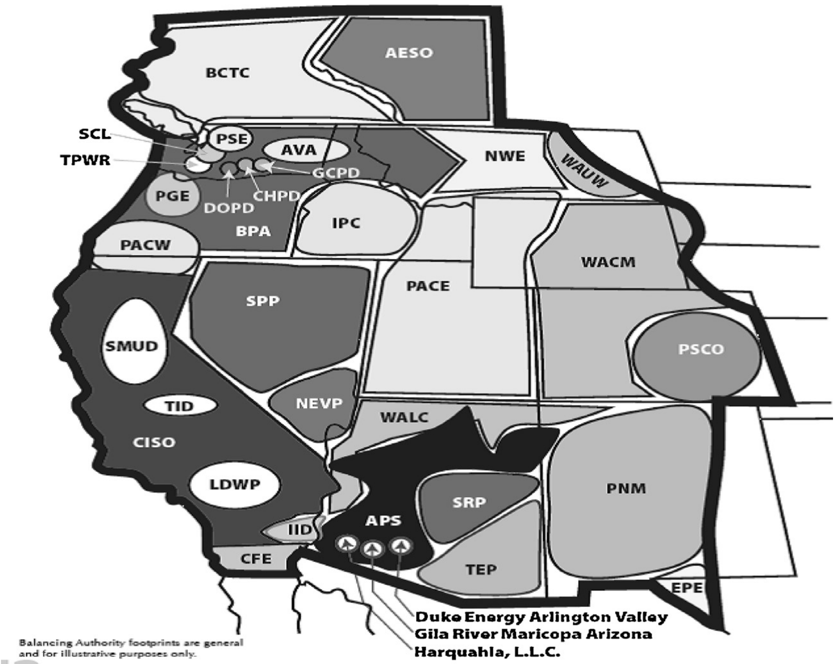


Figure 1: The WECC's 37 Balancing Authorities (map provided by Federal Energy Regulatory Commission)

reluctant to address reliability issues particularly if there are expected compliance difficulties [1]. Reliability is increasingly an issue in the WECC largely due to the impacts of variable energy resources (VERs), which require firm energy to backstop intermittent production.

A comprehensive overview of the recent history and expected trends in the evolution of capacity, production, and demand within the Western Interconnect is provided in [2]. In this article, we focus on the impacts of aggressive policies that resulted in the addition of significant variable energy resources within the Western Interconnect, examine the investment in transmission circuit-kilometers, and show the utilization rates for various generating technologies.

II. Renewable Energy Policies and the Growth in Variable Energy Resources

One of the most notable features of the WECC, and a fact that is highlighted in [2], is the abundance of low-carbon (nuclear, hydroelectric, wind, solar and geothermal) generation capacity that is currently in place and the significant additional low-carbon generation capacity that is expected by 2020. There are two distinct mechanisms responsible for the growth in low-carbon energy: government policies that set renewable portfolio standards/clean energy goals and investors' profit-maximizing behavior.

Renewable portfolio standards (RPS) exist in all but five of the U.S. states in the WECC, the exceptions being Idaho, Wyoming, Nebraska, South Dakota and Utah (South Dakota and Utah have created ''goals'' rather than a legislated target). In the other nine states the RPS requires renewable energy to comprise between 15 percent and 33 percent of total generation [3]. A summary of the WECC-US RPS goals is provided in **Table 1**.

States located within WECC-US have implemented aggressive RPS goals, particularly when compared to the RPS goals applied in the non-WECC US states. One explanation for the inconsistent adoption of RPS targets across states can be found in [4]. In **Figure 2**, we show the energy obligations resulting from state RPS goals for WECC-US states as a percentage of total available generation, assuming that available capacity is fully available and generates at its nameplate rating each hour throughout the year. This provides a ''capacity factor'' type of measure. We compare this value to the same metric for the far larger number of non-WECC U.S. states. We include Texas in the non-WECC group, as only a very small portion of Texas is included in the WECC [5]. Clearly, the WECC-US energy obligations from RPS are far greater than those in the non-WECC-U.S. states, despite the already substantial amount of low-carbon capacity installed in the WECC.

In Canada, the Province of British Columbia created the Clean Energy Act, which legislated that at least 93 percent of

  http://dx.doi.org/10.1016/j.tej.2013.04.015

Please cite this article in press as: A. Sopinka, Variable Energy Resources: VERy Interesting Implications for the Western Interconnect, Electr. J. (2013), http://dx.doi.org/10.1016/j.tej.2013.04.015

Table 1: Summary of Renewable Portfolio Standards in the WECC-US.

State	Renewable Portfolio Standard	Notes
WA	15% by 2020	Extra credit for solar or customer-sited renewables
OR	25% by 2025	Large Utilities
	5–10% by 2025	Smaller Utilities
CA	33% by 2020	
AZ	15% by 2025	
NM	20% by 2020	Investor-owned utilities
	10% by 2020	Co-ops
UT	20% by 20205	Renewable portfolio goal
NV	25% by 2025	Extra credit for solar or customer-sited renewables
MT	15% by 2015	
CO	30% by 2020	Investor-owned utilities
	10% by 2020	Co-ops and large municipals
TX	5,880 MW by 2015	Extra credit for solar or customer-sited renewables
SD	10% by 2015	Renewable portfolio goal
NE	None	
ID	None	
WY	None	

electricity generation would come from clean or renewable resources. This differs from an RPS, as the provincial Cabinet determines both the generation mix and which technologies can be used to meet the clean standard; nuclear generation is prohibited, as are any future storage hydro projects while run-of-river, wind, and solar technologies are encouraged. Natural-gas-fired generation used in support of liquefied natural gas (LNG) projects for export is exempt from the 93 percent ''clean'' target but will likely be subject to the $30/tCO_2$ provincial carbon tax and may also be required to purchase carbon offsets from the government's sole source, Pacific Carbon Trust. To date, British Columbia has long-term contracts to purchase 2978 GWh of VERs.

Alberta's electric grid is deregulated and all choices pertaining to the generation mix are made by investors. Over the last decade, Alberta has integrated over 925 MW of low-carbon capacity, almost exclusively wind facilities, resulting in a VER penetration rate of 9 percent based on winter peak load [6]. Alberta does impose a $15/tCO_2$ tax on large emitters including electricity generators that produce over 100 kilotonnes of CO_2e.

Mexico has two policies that impact carbon emissions resulting from electricity production. The first, known as the Special Program for Climate Change, requires greenhouse gas emissions reductions by 50 percent in 2050 over 2000 emissions levels while the Mexican National Energy Strategy states that by 2024 renewable energy capacity should be 35 percent [7,8].

The growth in low-carbon generation driven by the RPS goals stated in Table 1 and shown for WECC-US in Figure 1, were largely aimed at reducing the carbon emissions from electricity generation although there are certainly other benefits, including economic development. Whatever the underlying reason for the push towards renewables, the effect of the U.S. RPS's, BC's Clean Energy Act, and Alberta's investor-driven process is to deeply impact the capacity additions required for VER support. As variable energy resources, such as wind, run-of-river, and solar penetrate the grid, they require additional firm generation to backstop their intermittency.

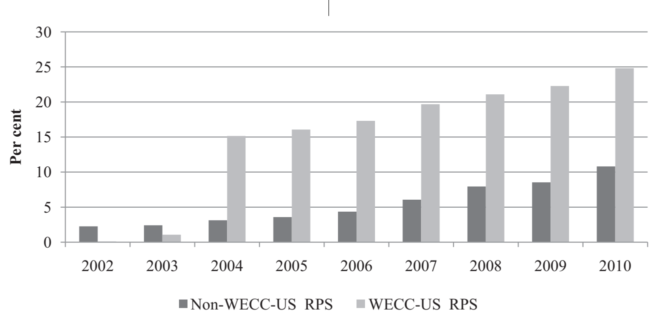


Figure 2: Energy Obligations Resulting from RPS in WECC-U.S. and Non-WECC U.S. States, Normalized in Terms of Generation Capacity

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2013.04.015

According to the North American Electric Reliability Corporation (NERC), the increase in VER necessitates additional transmission to smooth the intermittent output across a broader region and to deliver ramping capability and ancillary services [9]. In a grid without transmission constraints, the location of these firming resources can be geographically disperse.

III. Investment in Transmission Infrastructure

When transmission constraints impede the flow of electrons, the smoothing of output cannot be rectified by geographical dispersion. Moreover, ramping capability and ancillary services must be provided by additional generating units located within the region to overcome the transmission constraints. Although significant amounts of variable energy resources were added to the WECC system over the past 10 years, there was no corresponding increase in transmission circuit-kilometers.

By the end of 2011, WECC's internal transmission infrastructure included 207,224 circuit kilometers of wire that allows for the flow of electrons through the region. **Figure 3** shows the total circuit-km of wires by sub-region. The large increase between 2007 and 2008 is the result of a change in methodology at NERC, where <230 kV wire data was incorporated into the total values. At the end of 2011, WECC contained 204,417 circuit-km of AC wires and 2,807 circuit-km of DC lines with 320 circuit-km of AC transmission currently under construction [10]. Between 2010 and 2011, 3,988 kilometers of wires were added in WECC with the bulk of these new line additions (~60%) in WECC-CA [10,11]. Despite this late surge, the annual growth in >230 kV line additions averaged just over 1 percent per year since 2002.

The slow growth in transmission rollouts is one issue that the WECC is monitoring in terms of the impact on reliability. In the 2011 State of the Interconnect, the WECC noted that the organization will "continue to perform adequacy and planning margin assessments to identify its subregions . . . that have the potential for electricity supply shortages based on transmission constraints" [12].

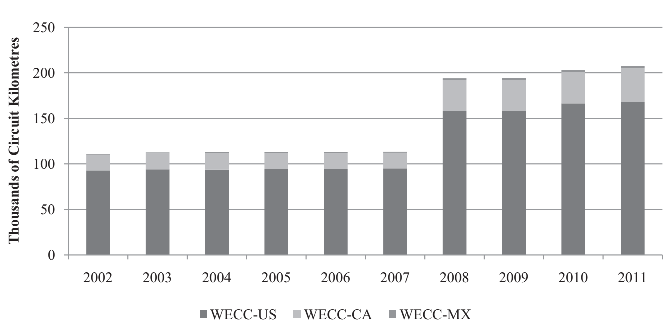


Figure 3: Total AC and DC Circuit Kilometers of Transmission within the WECC

IV. Requirements for Firm Dispatchable Energy

In transmission constrained areas with high variable energy resources, one of the workaround solutions is the development of firm and flexible generating units within the region. In a regulated system, the generation requirements can be prescribed. Deregulated markets use price to incent new investment. When prices are high, investors seek out profitable opportunities and build new generating facilities. As the supply increases, the price falls and thus signals a weaker investment climate. However, when must-take intermittent supply is added to the system, this zero-priced supply pushes down the average market price of electricity. This price-depressing effect is apparent in deregulated markets [13,14].

In California and Alberta, which operate deregulated electricity markets, the fidelity of the price signal is weak; low prices are reducing investment incentives in areas that require the firm supply and without a firm supply to replace the intermittent one, grid reliability issues are a distinct possibility. California faced a debilitating power shortage in 2001 and may be in store for another electricity crisis. The chief executive officer of the California Independent System Operator

  http://dx.doi.org/10.1016/j.tej.2013.04.015

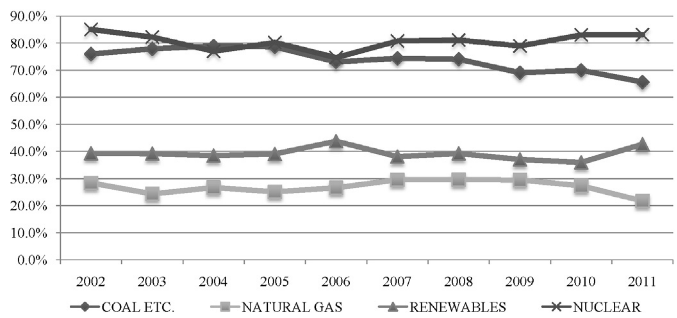


Figure 4: Utilization Rates for Differing Generation Technologies in the WECC

has alluded to these difficulties, stating that the ''problem is we have a system now that needs flexibility, not capacity'' [15].

Although this flexible and firm supply can come from any generation technology (or even demand-side response), typically it has been provided by natural-gas-fired generating units. The utilization rate for different generating technologies is shown for the years 2002–2011 in **Figure 4**. As expected, the utilization rates for nuclear and coal are relatively high as they are used to meet baseload demand. Renewables, which include conventional storage hydroelectric assets, have a utilization rate of approximately 40 percent.

The key conclusion to be drawn from Figure 4 is the low utilization rate for natural-gas-fired generating units. Combined-cycle gas-fired generators are used to provide baseload energy and are associated with a utilization rate in the 87 percent range while simple-cycle (or peaking) gas plants can have utilization rates around 30 percent [16]. Figure 4 shows that the fleet of natural gas units (both baseload and peaking) within the WECC has a combined utilization rate of less than 30 percent. If transmission were to be added to the system to manage the VER intermittency instead, those transmission paths would inevitably exhibit that same low utilization rate but at a greater capital cost. A natural-gas-fired generator has an overnight capital cost of about $650/kW [17] whereas the capital costs of transmission can range from $1-3 million per kilometer, a figure that does not include substation or right-of-way costs and assumes construction over flat and barren terrain. The construction of transmission lines over 15 kilometers in length would increase the capital costs by a factor of 50 percent [18]. In addition to the cost differential, the process of permitting, siting, and constructing transmission is approximately 7–10 years longer than the same process for installing generation capacity [10].

V. Conclusions

Variable energy resources require additional firm and flexible energy supply to backstop their intermittent production. This can be channeled from geographically disparate sources via the transmission system or garnered locally from nearby generating units. Within the WECC, the increase in natural gas capacity, the corresponding low utilization rate of that technology, and the stagnant structure of the transmission system implies that participants are choosing to add natural gas capacity, with its lower capital cost, rather than the more expensive, difficult-to-site transmission infrastructure. As RPS policies are expected to drive significant additional renewable generation into the WECC, the decision on whether to accept the low utilization of natural gas capacity or the low utilization rate of transmission paths will repeatedly be made.

Despite a sluggish history with respect to adding transmission circuit-miles to the bulk power system, current estimates are for over 25,000 transmission circuit-kilometers to be added in the next five years – an unprecedented achievement especially given the historic substantive delays associated with permitting, siting, and construction. However, adding expensive transmission capability that would inevitably have a utilization rate is not likely the lowest-cost scenario. If increasing the number of circuit-kilometers is deemed the appropriate solution to VER intermittency, the development of regional transmission operators may be required to oversee the evolution of transmission system. New ancillary markets may also be born out of

 1040-6190/$–see front matter http://dx.doi.org/10.1016/j.tej.2013.04.015

the nature of variable energy resources. These include energy imbalance, ramping, and firming markets. Jurisdictions that have firm energy resources that are also fast-ramping, such as British Columbia, Washington, and Idaho, with their large storage hydroelectric systems, are well-positioned to supply this much needed energy to the rest of the WECC.■

References

[1] WECC (2012), WECC Strategic Planning White Paper: WECC Executive Steering Team, at http://.www.wecc.biz/committees/BOD/20120829/Lists/Minutes/1/WECC%20STRATEGIC%20PLANNING%20WHITE%20PAPER%20FINAL%20-%20August%2023.pdf

[2] A. Sopinka and L. Pitt (2013), Trends in the Western Electricity Coordinating Council: Retrospect and Prospect, Pacific Institute for Climate Solutions White Paper, at www.pics.uvic.ca

[3] DOE (2012), *Database of State Incentives for Renewable Energy and Efficiency*, at http://www.dsireusa.org/documents/summarymaps/RPS_map.pdf

[4] L. Fowler and J. Breen, Mar 2013, *The Impact of Political Factors on States' Adoption of Renewable Portfolio Standards*, ELEC. J. , at 79–94.

[5] DOE (2013), LBNL RPS Compliance Data Spreadsheet.

[6] AUC (2011), Annual Electricity Data Collection, at http://www.auc.ab.ca/market-oversight/Annual-Electricity-Data-Collection/Pages/default.aspx

[7] Congressional Research Service (2009), *An Overview of Greenhouse Gas (GHG) Control Policies in Various Countries*, at http://www.fas.org/sgp/crs/misc/R40936.pdf

[8] Secretaria de Energia (2010), *National Energy Strategy*, at http://www.renovables.gob.mx/portal/Default2.aspx?id=1669&lang=2

[9] NERC (2009), *Accommodating High Levels of Variable Generation*, at http://www.nerc.com/docs/pc/ivgtf/IVGTF_Report_041609.pdf

[10] NERC (2012), *Long Term Reliability Assessment*, at http://www.nerc.com/page.php?cid=4|61

[11] NERC (2011), *Electricity Supply and Demand Database*, at http://www.nerc.com/page.php?cid=4| 38

[12] WECC (2012), *State of the Interconnection*, at http://www.wecc. biz/Planning/PerformanceAnalysis/Documents/2011_WECC_SOTI_Report.pdf

[13] J. MacCormack, A. Hollis, H. Zareipour and W. Rosehart, 2010, *The Large-Scale Integration of Wind Generation: Impacts on Price, Reliability and Dispatchable Conventional Suppliers*, ENERGY POLICY, 38 (7) at 837–3846. http://dx.doi.org/10.1016/j.enpol.2010. 03.004.

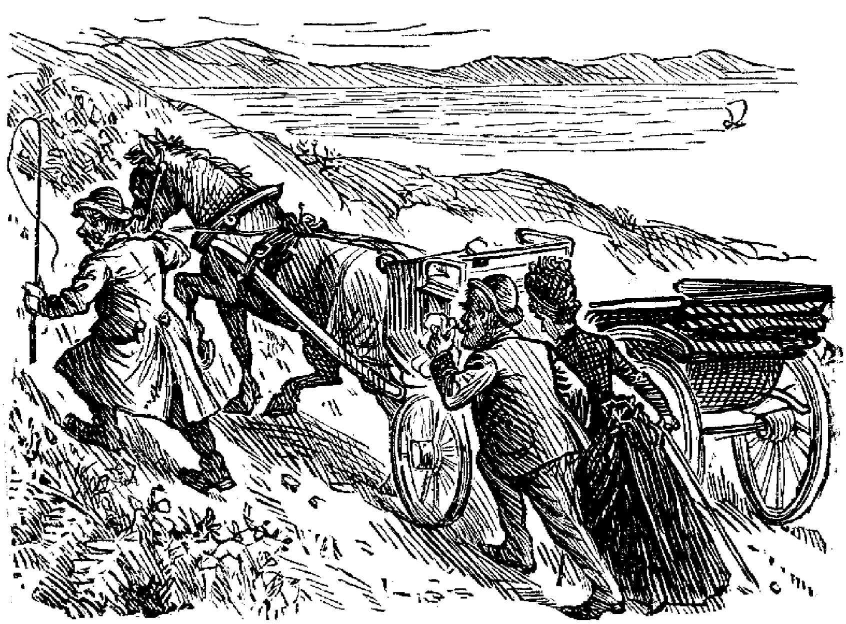
[14] California ISO (2012), *2011 Annual Report on Market Issues and Performance: Department of Market Monitoring*, at http://www.caiso.com/Documents/2011AnnualReport-MarketIssues-Performance.pdf

[15] WSJ (2013), *California Girds for Electricity Woes*, WALL ST. JNL., at http://online.wsj.com/article/SB10001424127887323699704578328581251122150.html?mod=googlenews_wsj

[16] EIA (2012), *Annual Energy Outlook 2012 with Projections to 2034*, at http://www.eia.gov/forecasts/aeo/pdf/0383(2012).pdf

[17] EIA (2010), *Updated Capital Cost Estimates for Electricity Generating Plants*, at ftp://ftp.eia.doe.gov/forecasting/updatedplantcosts.pdf

[18] WECC (2012), *Capital Costs for Transmission and Substations: Recommendations for WECC Transmission Expansion Planning*, at http://www.wecc.biz/committees/BOD/TEPPC/External/BV_WECC_TransCostReport_Final.pdf



This can be channeled from geographically disparate sources.

  http://dx.doi.org/10.1016/j.tej.2013.04.015

Please cite this article in press as: A. Sopinka, Variable Energy Resources: VERy Interesting Implications for the Western Interconnect, Electr. J. (2013), http://dx.doi.org/10.1016/j.tej.2013.04.015