CHAPTER

2

Policies for Accommodating Higher Penetration of Variable Energy Resources (VERs)—U.S. Outlook and Perspectives

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1. Recent renewable deployment trends

Over the last few years, renewable energy resources have witnessed an explosive growth in the United States. As shown in Figure 1, renewable energy sources, particularly wind, solar, and biomass, have been growing at a much higher rate than the conventional energy sources. In 2015, ∼13 GW of new wind capacity was added, increasing the total installed wind capacity in the United States to about 74 GW.

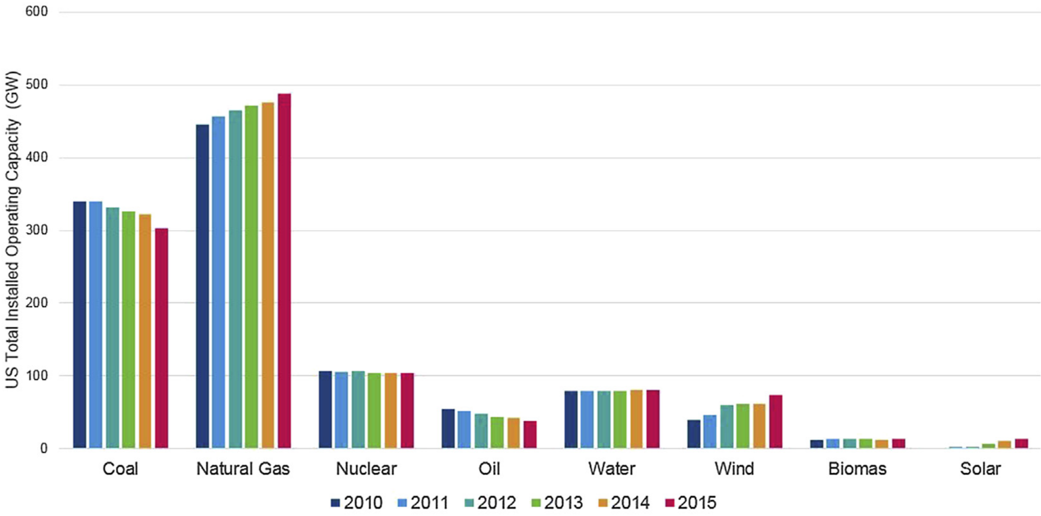

FIGURE 1

Total installed operating capacity in the United States by fuel type. (For color version of this figure, the reader is referred to the online version of this book.)

Source: ICF, data from EIA. US Energy Information Administration. Form EIA-860 detailed data, 3_1_GeneratorYyyyy. Available at: http://www.eia.gov/electricity/data/eia860/index.html [accessed on 11.22.16].

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While a number of factors, such as steep reduction in cost of wind turbines and abundance of good quality wind, have contributed to the impressive growth of wind energy in the United States, favorable federal and state policies deserve the most credit for this spurt in wind energy development. These include the federal production tax credit (PTC) and state renewable portfolio standard (RPS) policies.

1.1 Federal policy impacting growth—renewable electricity production tax credit

The federal PTC is a per-kilowatt-hour tax credit for electricity generated by utility-scale wind turbines, geothermal, solar, hydropower, biomass, and marine and hydrokinetic renewable energy plants and was originally enacted as part of the "Energy Policy Act" of 1992. The PTC has been a major driver of wind energy development over the past one and a half decades [2], its most recent extension in 2015 included only wind technology and incorporated a 5-year phaseout schedule until 2020. Projects are eligible for 100% PTC in 2016 and then decreasing 20% each year until 2020.

Wind energy development in the United States has historically relied heavily on the PTC. As shown in Figure 2, the wind industry experienced several boom—bust cycles with strong growth during the years leading up to the expiration of the PTC and a dramatic decrease in installed wind capacity in years when the PTC lapsed [3].

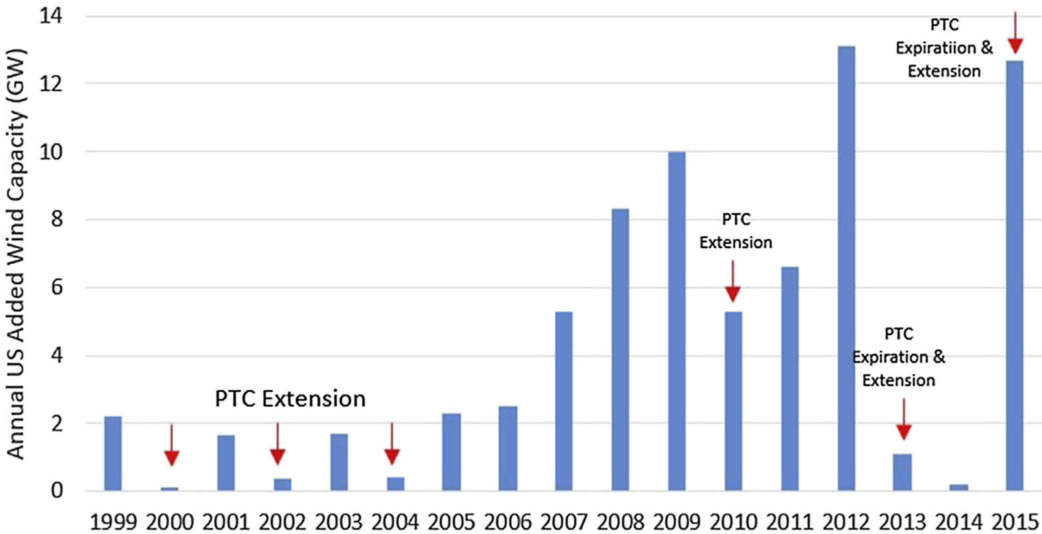

FIGURE 2

Impact of production tax credit (PTC) on annual wind installations in the United States. (For color version of this figure, the reader is referred to the online version of this book.)

Source: ICF, data from DOE and AWEA. US Department of Energy (DOE). WINDExchange, Installed Wind Capacity. http://apps2.eere.energy.gov/wind/windexchange/wind_installed_capacity.asp [accessed on 11.22.16] American Wind Energy Association (AWEA). http://awea.files.cms-plus.com/1Q%202014%20Bar%20Chart.png [accessed on 11.22.16].

1.2 State policy impacting growth—renewable portfolio standards

RPS policies place an obligation on electric supply companies to supply a specified fraction of their electricity from renewable energy sources and enumerate mechanisms that are permitted to achieve compliance, such as renewable energy credits (RECs).[1] Currently, 29 states and Washington D.C. have renewable electricity standards and 8 states have renewable portfolio goals [5]. The idea of federal RPS or clean energy standard has been discussed, but has never gained the necessary traction to become a law.

Along with the federal PTC, the state RPS mechanisms have been primarily responsible for inducing new renewable energy capacity in the United States over the last several years. In an environment of low gas prices, and the potential expiration of the PTC, the continuation of state policies, along with the continued improvement in wind turbine technology, will continue to be important in promoting the continued development of renewable energy resources.

2. Technical challenges posed by wind generation for power system operation and planning

The grid-based power system is continuously changing and is impacted by various factors that change in increments in time from seconds to minutes, minutes to hours, seasonally, and year to year. In the different timescales of operation, balance between load and available generation must be maintained. In the very short timescale—seconds to minutes—stability and reliability of the system is primarily maintained by automatic control systems such as automatic generation control.[2] In the intermediate to longer timescales, system operators and planners are responsible for maintaining system reliability through the use of operating and capacity reserves.

The inherent variability of wind and solar generation and the uncertainty in wind forecasts have impacts on the various timescales of the power system that range from a few seconds to years. Figure 3 shows the impact of wind and other generation on various aspects of power system in different timescales. While integration of renewables on the distribution system presents its own set of challenges, this chapter deals only with wholesale market level issues associated with renewable integration.

Some of the key inferences from variable renewable generation are summarized below, and this chapter helps identify the specific operation and planning challenges of variable renewable generation and wind generation in particular.

- The stability of the power system is governed primarily by synchronous generators supplied from conventional base load and dispatchable resources. Displacement of conventional generators by wind generators can adversely impact system stability by reducing the system inertia, posing challenges to maintaining power system stability.
- Variations in wind energy and demand within an hour are much more significant for the system. Adequate fast ramp reserve capacity in the form of generation or energy storage is required to

[1] The Environment Protection Agency (EPA) of the United States defines REC as: “REC represents the property rights to the environmental, social, and other nonpower qualities of renewable electricity generation. An REC, and its associated attributes and benefits, can be sold separately from the underlying physical electricity associated with a renewable-based generation source.” More details can be found at http://www.epa.gov/greenpower/gpmarket/rec.htm.

[2] Automatic generation control is an automatic control system for constantly adjusting the output of generating units at different power plants, in response to moment by moment variations in the load.

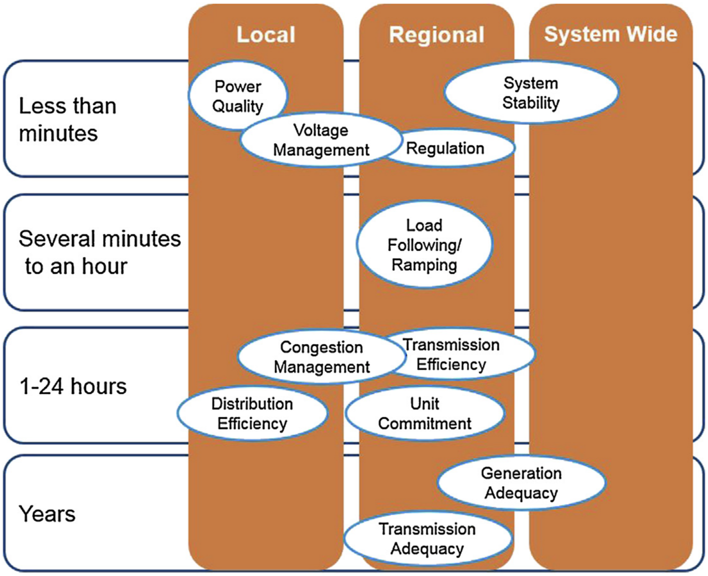

FIGURE 3

Impact of wind energy on various aspects of power system. (For color version of this figure, the reader is referred to the online version of this book.)

Source: ICF.

manage variability of wind generation over this time frame. System operators deploy appropriate backup resources with quick start capability to follow the variable nature of wind generation. Energy storage resources offer twice the nameplate capacity because of their ability to both inject and absorb from the grid (ability to act as both generation and load); this is particularly valuable in enabling renewable integration as it helps address overgeneration and avoid curtailment while providing highly flexible ramping capacity to the system.

- Integration of wind generation is likely to increase the commitment of quick start units to ensure available generation to handle deviations from forecast levels. On the other hand, the increased use of renewable generation typically displaces generation from thermal resources such as gas and coal-fired power plants. For example, in the California Independent System Operator (CAISO) system, grid operators expect that in year 2020 with high levels of renewable penetration, conventional units may face a ramping need of over 13,000 MW in 3 h (Figure 4). In large part, this is driven by an increase in solar photovoltaic (PV) generation, which has a significant drop-off in capacity in the late afternoon hours (5—7 p.m.). Absent significant reductions in peak, adequate—and significant—levels of quick-ramp capacity would be required to ensure reliable system operations under such circumstances. And while wind resources generally have a more diverse generation profile, they are typically located far from the load, which requires additional investments in transmission infrastructure. New transmission lines remain underutilized if built to accommodate the full capacity of a wind farm due to relatively low wind capacity factors. On the other hand, if lines are undersized, curtailment of wind generation can occur.

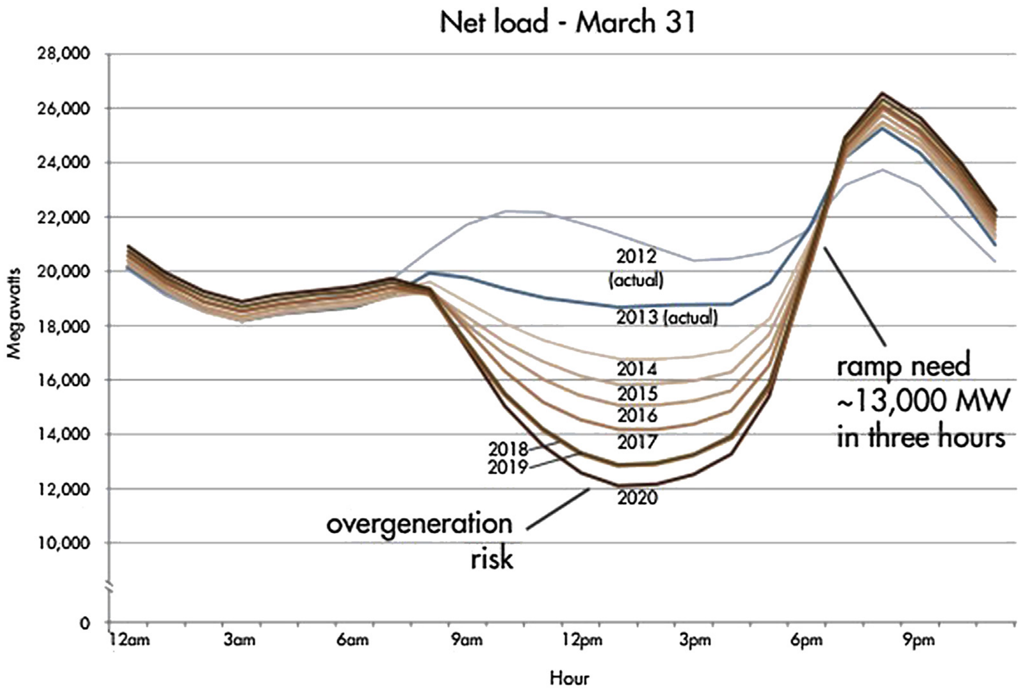

FIGURE 4

California Independent System Operator (CAISO)—ramping needs (CAISO's duck curve). (For color version of this figure, the reader is referred to the online version of this book.)

Source: CAISO; Manasseh O, Robert B. Trends and challenges of grid-connected photovoltaic systems – A review. Renewable and sustainable energy reviews. Elsevier; May 2016.

3. Economic challenges associated with high wind energy—the potential for curtailment

Wind curtailment, where the system operator cuts the amount of wind generation that can be sold onto the power grid for a specified amount of time, is usually caused by one of the two factors: a transmission system that is incapable of accommodating the full dispatch of wind facilities (involuntary curtailment) or a mismatch between supply and demand (voluntary curtailment).

Voluntary curtailment manifests itself in nodal pricing markets, such as PJM, New York, New England, and Electric Reliability Council of Texas (ERCOT), in the form of low or even negative power prices (meaning generators must actually pay to produce wind power). Wind power producers respond by reducing their output. Operators that also own coal or nuclear facilities may voluntarily curtail wind power production because wind power plants require less time and money to shut down and restart in comparison to conventional generation facilities.

Involuntary wind curtailment represents the greater and more common challenge. System operators faced with congestion overloads order wind producers to reduce their output or cease operations to preserve system reliability. Involuntary curtailment occurs most frequently for those wind power producers in traditional contract paths with nonfirm transmission service contracts and no minimum price bids. Regions that have seen relatively high levels of involuntary wind curtailment include the Pacific Northwest, ERCOT (before the development of transmission projects), Midwest ISO (before some market changes were implemented), and SPP. The reported percentage of wind curtailment by region is described in Figure 5.

Typically, contracts in nodal markets are structured so that generators assume economic risk and buyers assume the reliability risk. Buyers pay the wind power producer a set contract price, regardless of the spot-grid prices at the seller's location. Even if buyers request curtailment, they may be contractually obligated to reimburse the seller for lost revenue. Coupled with the likelihood that the wind producer will lose other revenues, such as the PTC, contingent on operating the wind generator, the wind power seller has no incentive to adjust output in response to low prices. Therefore, the transmission provider must request an involuntary curtailment to maintain reliability.

Environmental factors can also prompt involuntary curtailment. In the Pacific Northwest, for example, transmission providers facing overloads caused by rising water levels occasionally curtail wind, thermal, and other energy sources in favor of hydropower to protect and preserve wildlife habitat.

3.1 The repercussions of discarded energy

When usable energy is curtailed, all parties involved suffer financial consequences. These include the following:

- *Lost revenues*—Wind curtailment prevents lenders and other investors who invest in wind power production from receiving the returns they expected.

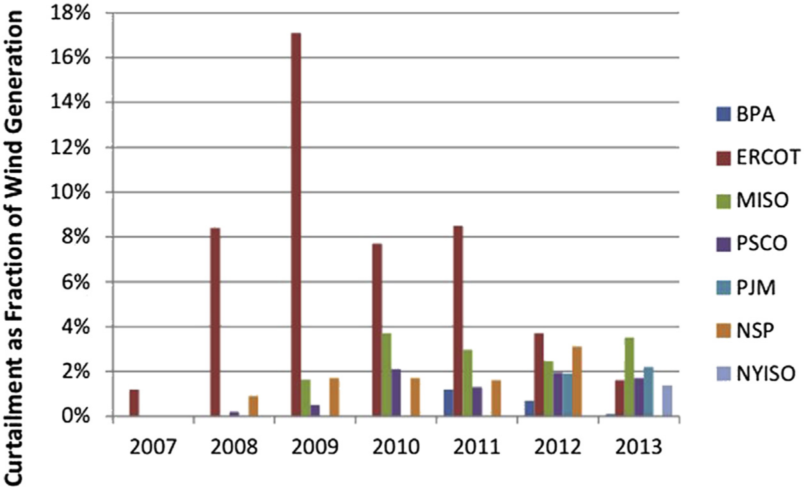

FIGURE 5

Wind curtailment by region (2007—2013). (For color version of this figure, the reader is referred to the online version of this book.)

Source: NREL; Brid L, Cochran J, Wang X. Technical Report NREL/TP-6A20-60983, wind and solar curtailment: experience and practices in the United States. National Renewable Energy Laboratory; 2014. http://www.nrel.gov/docs/fy14osti/60983.pdf [accessed on 11.09.16].

- *Lost incentives*—Wind power producers who qualify for valuable PTC that is equal to 2.3 cents per kilowatt-hour on an after-tax basis for the first 10 years of electricity production. They can also earn Renewable Energy Certificates or a green power premium effectively bundled in the energy sales for their generated power. But wind producers only earn these rewards if they operate their facilities and distribute their wind power on the grid. However, some states such as Colorado wind producers will still be compensated on energy production plus PTC, if curtailment is caused by balancing purposes [7].
- *Higher energy prices*—Wind power producers may need to charge higher prices to help offset the risks of revenue lost to curtailment or negative pricing. Negative pricing occurs when wind power producers opt to pay grid operators to take their power so they can still earn PTC and REC benefits.
- *Challenges to business operations*—Wind power producers face competition from generators of coal, gas, hydropower, and other energy sources that face little to no exposure to curtailment risks. Furthermore, the risks and uncertainties of curtailment can make it difficult for new wind power producers to secure funds from financing agencies.

Certain markets such as the Midwest ISO have instituted programs called "Dispatchable Intermittent Resources (DIR)" to ensure that wind units follow price signals and change their dispatch accordingly. As of 2015, almost all the wind generation in Midwest ISO is dispatchable, which has reduced the instances of involuntary curtailment and made almost all of the curtailment to be on economic basis. Such market changes are encouraging for wind generators primarily because it provides greater transparency in control actions taken by the grid operator. Transparency is particularly helpful while making decisions on the size, location, and market for power plant developers and utilities that subscribe to renewable capacity. It also helps plan, mitigate, and hedge against the risk of curtailment more effectively.

However, this development still does not take away the risk of curtailment of wind energy; it just makes it more manageable. Additional transmission development and broadening the market's footprint are some of the fundamental ways of reducing overall levels of curtailment. By leveraging resources across a broader area, the volatility associated with wind can be effectively minimized.

4. Transmission development for wind integration—challenges and success stories

Central station renewable resources are typically located far from networked transmission lines, requiring developers to design and construct transmission systems specifically designed to transfer the power generated by the renewable energy systems. Construction of transmission lines is a challenging process for the following reasons:

1. Long lead time associated with obtaining necessary permits and approvals (typical high-voltage lines face a 5−7 year lead time)
2. Cost allocation within utilities in the region
3. Environmental issues and local citizen activism (not in my backyard or NIMBY issues)
4. Siting and permitting challenges with local state and municipal agencies

Federal Energy Regulatory Commission (FERC) Order 1000 provided a framework for incentivizing transmission development for achieving public policy objectives such as renewable energy targets. Consequently, it is possible that in the near future additional transmission may be developed in certain regions to facilitate renewable integration, with the costs allocated among multiple parties that benefit from the project.

However, there have also been several challenges for transmission—most notably the explosive growth of distributed energy resources (DER). DERs can provide reliability benefits to the system in the form of deferred transmission and distribution upgrades if targeted in specific localities. The class of DER's that include energy efficiency, demand response (DR), energy storage, and combined heat and power applications has the effect of reducing peak demand by providing appropriate incentives to customers to lower energy consumption during stressed grid conditions. In many markets across the country, demand resources provide valuable peak capacity to address resource adequacy issues in capacity markets. Large transmission projects planned in this region, such as the Mid-Atlantic Power Pathway (MAPP), have been deferred due to weak growth in peak demand, partly due to an increase in DERs, and specifically DR. (See chapter by Ott about DR in PJM.)

4.1 State policy examples to incentivize transmission system development to accommodate renewable generation

Some states have successfully developed transmission facilities to accommodate large amounts of traditional and renewable generation in a short span of time. Understanding the success factors and the challenges faced through the transmission development process can be a critical step in the development of transmission infrastructure to accommodate renewable generation. However, with the advent of flat to decreasing load due to increasing load management and distributed generation, the building of large transmission projects faces additional pressures.

4.1.1 Texas planning example

The competitive renewable energy zones (CREZ) of the ERCOT is a major success story of planning transmission for integrating large amounts of utility-scale wind power into the electric grid. By identifying regions with good wind energy potential and sufficient land area to generate electricity, ERCOT was able to develop a transmission expansion plan that would enable delivery of about 18,000 MW of wind energy to load centers. The plan was approved by the Public Utilities Commission of Texas (PUCT) in 2008, and all the transmission facilities identified in the plan were completed by 2014. Figure 6 shows a timeline of key milestones in CREZ.

As previously stated, development of new transmission is a fairly long process due to several contentious issues related to cost allocation and transmission siting. The CREZ transmission projects were completed in early 2014 in a span of 8 years, which is relatively a very short duration for the scale of transmission development (~2300 miles of 345 KV lines) that will take place in CREZ. Some of the key factors that have played a role in the success of Texas–CREZ are listed in Figure 7.

4.1.2 California renewable and transmission development example

Another major transmission development project for integrating large amount of utility-scale wind energy resources is the Tehachapi Renewable Transmission Project. Southern California Edison

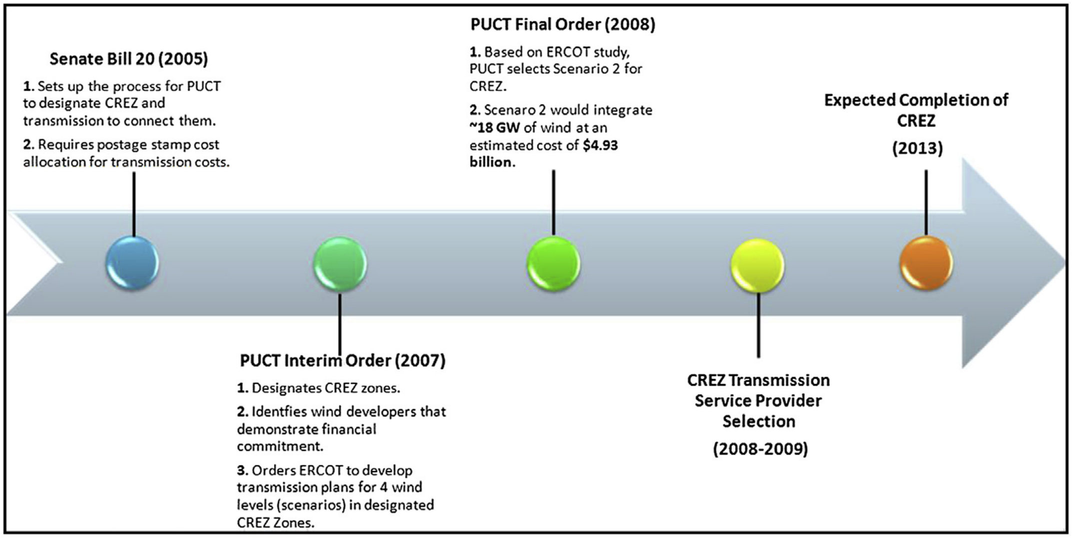

FIGURE 6

Evolution of CREZ.

CREZ, competitive renewable energy zones; ERCOT, Electric Reliability Council of Texas; PUCT, Public Utilities Commission of Texas. (For color version of this figure, the reader is referred to the online version of this book.)

Source: Hunt Transmission LLC, Sharyland Utilities, and ICF.

(SCE), one of the three investor-owned utilities in California, is currently constructing transmission facilities that will enable about 4,500 MW of wind energy from the Tehachapi region to be delivered to the distant load centers. Segments 4—11 of this project were expected to be completed by the end of 2016.

The major driver behind this project is the aggressive RPS goal set by California. Wind energy resources in Tehachapi could play a significant role in achieving the RPS goals, but transmission constraints from the California high desert to load centered in the Los Angeles (LA) Basin needed to be overcome. This transmission project helps alleviate such constraints.

Cost recovery was the major impediment for this project due to the “chicken and the egg” problem—major transmission additions and their cost allocation processes cannot be approved by the California Public Utilities Commission (CPUC) until sufficient generator commitments have been obtained, and without sufficient transmission, generator commitments are hard to obtain. Due to FERC’s jurisdiction over wholesale transactions on SCE’s transmission facilities, the CPUC only had a “backstop” authority to approve cost recovery for the project through an increase in electricity rates of SCE’s retail customers. To ensure that the burden of the project is also shared by all the generators that benefit from the transmission development, the CPUC encouraged the CAISO to prepare a policy and urged FERC to approve it, which will extend the cost allocation “backstop” authority to include location-constrained generators. As a result, CAISO prepared and FERC approved the Location Constrained Resource Interconnection (LCRI) policy in 2007. Through the LCRI, retail customers of

Index	Factors	Responsible Players	Impact
1	Government mandate for CREZ and clearly stated cost allocation method (postage stamp) through Senate Bill 20 (SB 20).	Legislature and State Government	Reduced investment risk for wind power and transmission investors and developers.
2	SB 20 requirement for PUCT to designate best areas for renewable energy development that satisfy the following criteria: 1. Availability of best quality renewable resources. 2. Availability of sufficient land area for generating power from renewable resources. 3. High level of financial commitment from renewable energy developers.	Legislature and State Government	Credible selection of CREZ zones that would increase benefit to cost ratio
3	Transmission Optimization Study by ERCOT to identify optimal transmission plans for 4 levels of wind generation development in PUCT identified CREZ zones	PUCT and ERCOT	The study enabled the selection of a wind generation scenario in CREZ zones that maximized wind power generation at optimal transmission development cost.
4	Competitive Selection of Transmission Developers	PUCT	Those transmission plans and developers were selected for implementing CREZ which would maximize consumer benefits at lowest possible cost.
5	Allowing utilities selected for developing CREZ transmission to include associated costs in their rate base	Legislature and State Government	Further reduction in financial risk associated with transmission development.

FIGURE 7

Texas success story—development of CREZ.

CREZ, competitive renewable energy zones; ERCOT, Electric Reliability Council of Texas; PUCT, Public Utilities Commission of Texas. (For color version of this figure, the reader is referred to the online version of this book.)

Source: ICF.

SCE have initially underwritten the complete project, and as new wind generation projects in Tehachapi use the transmission facilities, they will bear the burden of the project cost.

4.1.3 Midwest ISO multivalue project cost allocation mechanism

Midwest ISO uses a multivalue construct for cost allocation of high-voltage transmission projects within its footprint. FERC approved this mechanism in December 2010 to implement a region-wide cost allocation for special high-voltage transmission projects, which provide multiple benefits known as multivalue projects (MVPs). MISO primarily planned to build MVPs to evacuate clean energy generated largely in the northwest region by wind farms to load centers in the Midwest and Mid-Atlantic region; in addition, it provides reliability and various economic benefits distributed over multiple price zones.

4.1.4 Merchant transmission example for VER integration—Tres Amigas

4.1.4.1 Tres Amigas

The Tres Amigas is a superstation that will employ the latest in power grid technologies, including superconductor cables, voltage source converters, and energy storage systems to interconnect the nation's three individual power grids known as the Eastern interconnection, the Western interconnection, and the Texas interconnection.

The regions in the Western interconnection are solar energy-rich regions whereas Texas has the best wind in the nation, but weak transmission network is a major impediment for the development of renewable capacity in this region. Also, the variable and uncertain nature of renewable generation makes it difficult for system operators to maintain system reliability under high-renewable penetration. The larger integrated grid reduces variability and uncertainty in the renewable generation and reserve requirement also reduces because greater geographic distribution of renewable resources reduces the variability in renewable generation. The Tres Amigas located in the eastern region of New Mexico near the border of Texas will unite America's isolated interconnection grids; it will allow renewable resources to utilize larger integrated grid and move clean power over long distance. The Tres Amigas station will have 5 GW of power transfer capacity in the initial phase but eventually could move up to 30 GW of transfer capacity.

5. FERC Order 764 on VER Integration

On June 2012, FERC issued the final rule on Order No. 764, which is intended to remove barriers for the integration of variable energy resources (VERs) into the grid. As per the Order, VER is a device employed for the production of renewable power that cannot be stored and has variability in the output, which cannot be controlled by the operator or the owner. The Order requires transmission providers to amend their open access transmission tariff (OATT) to allow 15-min intra-hour scheduling of transmission services by all generators including VERs that want to make such intra-hour scheduling additions or changes. FERC noted that the resources pay for imbalance charges for any deviation between its scheduled energy for a particular hour and actual energy generated in that hour. FERC pointed to the fact that VERs are subject to huge variations within a short period and that the existing rules do not allow resources to adjust their power within the hour to avoid imbalance charges. Consequently, the FERC ruling requires transmission providers to transition from hourly to 15-minute transmission scheduling. With VERs input close to real time, it becomes difficult for the system operator to manage operations during real-time conditions. Therefore the Order requires transmission providers to amend the Large Generator Interconnection Agreement (LGIA) to require new VERs to provide meteorological and forced outage data to the transmission providers who perform power production forecasting.

On December 20, 2012, FERC issued Order No. 764-A to address rehearing and clarification requests received from multiple parties. In the Order, FERC confirmed that the intra-hour scheduling reforms apply to all the transmission customers scheduling transmission service under the OATT, which includes entities using point-to-point service or opting for network integration service. In addition to that, FERC also cleared that transmission providers must average the imbalances of each 15-minute scheduling interval over the entire hour for customers that schedule transmission service at 15-minute intervals so as to reduce the imbalance charges for these customers. FERC also clarified that firm transmission schedule holds curtailment priority over nonfirm schedules. In summary, FERC actions through Order 764 should facilitate the integration of higher levels of VERs on the system.

6. The future of renewable development in the United States

With continuing falling costs and the extension of the PTC and ITC (investment tax credit), the future of central station renewable resources looks bright. Increasingly in the United States and globally, we are noticing steep declines in the capital cost of renewable resources, particularly solar PV. Latest price points of renewables suggest that even with sustained low natural gas prices, renewable resources will be significantly more attractive to utilities and corporate off-takers given the expected cost declines and environmental attributes. There is also an emerging trend of large corporations directly contracting or opting to own renewable resources, another indicator that corporate sustainability is driving additional growth in this segment.

The development of both DER and central station renewables is going to continue and operate, planners need to work on appropriate methods to successfully integrate these resources into the grid. Effective federal and state policies related to measures needed for renewable integration and market design to accommodate the variability concerns would be critical items to watch for in years to come.

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