ISO RULES FOR INTERMITTENT GENERATION

TODD RYAN, CARNEGIE MELLON UNIVERSITY

Introduction:
America is pushing ahead to build up renewable generation capacity with many agencies struggling to find ways to reliably hit their renewable portfolio goals. A National Renewable Energy Laboratory study highlighted the need for increased transmission capacity (NREL 2008) while the Federal Energy Regulatory Commission is asking for the industry's input into how policy, rules, and regulation need to be adjusted (FERC 2010). This paper aims to provide a high-level introduction to how electricity markets have, to date, integrated renewable generation into their market structures and highlight the critical rules by which renewable generation participate in America's electricity markets. Additionally, this paper explains how these rules differ from those for traditional generation in order to give reference to the requests by the industry to FERC. This paper focuses on the regional deregulated electricity markets and uses their market tariffs as the basis for understanding how renewable generation provides different services to the grid including capacity, energy, and ancillary services.

Regional Market Operators:
Market suppliers (such as electricity generators and other entities that provide services to the grid) bid in to provide a service (be it energy, ancillary services, or capacity), creating a supply curve for each service. Market buyers bid in to consume a service creating the respective demand curves. The Independent System Operator (ISO) or Regional Transmission Operator (RTO)[1] then identifies which suppliers are needed to meet demand, sets the prices, handles scheduling of resources, and finally, manages the financial accounting and settlement between suppliers and consumers. In short, the ISOs keep the lights on while attempting to minimize cost.

The market operators also provide another key function: they document and write all the rules that determine how the markets function. The rules clearly outline the responsibilities of each party (ISO, seller, and buyer). These rules must be approved by the Federal Energy Regulatory Commission (FERC) to ensure that they are appropriate, just, and treat all participants comparably. In short, the rules need to give each participant fair and equal access to the transmission network and electricity markets (FERC 2007).

How Do the ISOs make Rules specific to Wind and Solar?
Given that the ISOs need to treat all participants comparably, it can be difficult to write technology-specific rules. Opponents of such rules could easily argue that such rules were discriminating against some technologies or favorable towards others. To avoid such situations, the ISOs generally define asset types that are not technology specific, but that generally describe a set of technologies with similar attributes. For example, renewable generation resources such as wind or solar have been grouped into an asset class[2] (such as "Intermittent Generation") that describes their inherent difference with traditional generating resources. The ISO's job is not to create policy, and therefore, it does not care what type of fuel generated that megawatt-hour; rather the ISO cares about the fact that wind and solar generation cannot be scheduled because of its dependence on natural phenomena. Creating market rules that apply to Intermittent

1 There are six regional markets: ISO New England (ISO-NE), New York ISO (NYISO), PJM Interconnection (PJM), Midwest ISO (MISO), Electric Reliability Corporation of Texas (ERCOT), and California ISO (CAISO). Here we will use the term ISO to mean both ISOs and RTOs.

2 For example, NYISO uses "Intermittent Power Resource"; section 2.9, sheet 35 of NYISO Market Services Tariff
MISO uses "Intermittent Resource"; section 1.329, sheet 184 of MISO Tariff Modules

Generation will allow the ISO to distinguish between solar and wind from traditional generation without discriminating between solar and wind. These asset-specific rules dictate the integration of such intermittent resources into the current grid. This is the general approach taken by the ISOs and by FERC. FERC uses the term Variable Energy Resources (VER), and for simplicity, so will we.

Interconnection Requirements:
Before a wind farm can start selling energy into the electricity markets, it first needs to interconnect into the transmission network and to do so the wind farm must meet the ISO's interconnection standards.[3] These standards and procedures are very similar to that of traditional generation other than for two key areas: 1) forecasting and telemetry, and 2) Low Voltage Ride-Through. For these two areas, the ISO's have developed specific rules for VERs.

Forecasting and telemetry
The production from a wind farm is not a completely random variable. Given an estimate of the wind speeds, direction, and some understanding of the specific parameters of the wind farm, it is possible to predict the output with some degree of certainty. In order to allow the ISO to be able to anticipate each VER's production and to be able to plan ahead accordingly, the ISO's require each wind farm to subscribe to a forecasting service and to have a minimal amount of telemetry to feed into the forecasting model.

Low Voltage Ride-Through
Low Voltage Ride-Through (LVRT) is an interconnection requirement that was developed by the Federal Energy Regulatory Commission in their order on "Interconnection of Wind Energy" (FERC 2005) and refined after lengthy litigation in FERC Order 661-A (FERC 2005). LVRT specifies how long a wind turbine needs to remain online during any event in which the voltage on a single leg or multiple legs of the interconnecting transmission line drops. In such events, inductive-generator wind turbines lose the ability to produce electricity, are forced to trip offline, and in turn make the voltage drop even more. Through this mechanism, the wind turbine could contribute to a cascading blackout. Low Voltage Ride-Through specifies that wind turbines must stay online for at least 0.15 seconds (nine cycles at 60 hertz) during any phase fault before tripping offline. Although this is a technology specific regulation, it is considered as 'comparable treatment' because the standard requires the same level of reliability regardless of technology. In response to this measure of reliability many wind farms use static VAR compensators, power electronics, and have adopted new turbine generator.

These two interconnection requirements seem, at first, to be only for wind and not include solar energy facilities. The justifications for excluding solar from the these requirements have been: 1) the majority of solar installations are on distribution networks where they are regulated by the state and interconnecting utility; 2) solar facilities innately require power electronics that can meet the LVRT and power factor requirements in order to invert their DC power to AC; and 3) the meteorological data needed to predict a solar facility's output is less site dependent and easier to predict. As solar penetration on the grid increases, I would expect that solar will be included in these requirements.

---

[3] For full details on interconnection stands, see the Large Generation Interconnection (LGIP) Procedure for the respective region.

Electricity Market Services:
Each individual ISO, through its own internal stakeholder process and given approval by the Federal Energy Regulatory Commission, will decide which services are needed and the procedures necessary to implement that product. Each ISO generally has similar, if not identical, products that can be generalized into three main groups: Energy, Capacity, and Ancillary Services.[4]

1) **Energy**

   Energy is usually sold in two different ways: through a physical market that results in the dispatch of resources; and a financial market that is only financially binding and does not necessarily result in the dispatch of generating resources. When a financial market exists, it is usually called the Day-Ahead market and solves for hourly energy prices at least a day prior to the respective pricing period. The physical market always exists and usually corresponds to the Real-Time market. This market creates energy prices that reflect the current system conditions every five to fifteen minutes.[5] The exceptions to this are ERCOT and CAISO, which have physical Day-Ahead markets and Real-Time incremental markets (*i.e.,* doesn't solve for the price of total demand, but only the additional demand needed). For simplicity, we will assume the convention of day-ahead markets being financial and real-time markets being physical unless specified otherwise.

   The ISO serves multiple roles in the Energy market including solving for the price of energy, scheduling and dispatching generating resources, and settlements. All of these roles have very specific rules associated with them and most have VER specific rules.

   Scheduling

   It is very common for ISO's to schedule VERs based on their forecast. This makes sense given that the forecast is the best estimate of what a VER will produce. This is in contrast to traditional generation, which has the option of being economically dispatched or setting its own schedule. VERs are forced to be economically dispatched and capped at their forecasted value.

   Dispatch

   VERs are defined by not being dispatchable. For example, the Midwest ISO definition of an Intermittent Resources is:

   "A Resource that is not capable of being committed or decommitted by, or following Setpoint Instructions of, the Transmission Provider in the Real-Time Energy and Operating Reserve Market."

   Section 1.329, sheet 184
   MISO OATT (MISO 2010)

   There are a few ISO's, and limited circumstances, where VERs are dispatched downward. This usually occurs where there is a significant line constraint that limits or prohibits the export of power from that VER. It can also be used to limit the ramp rate of a facility as it starts up or shuts down. For example, the NYISO sends each wind farm

---

4 The words "energy" and "capacity" can often mean two things when talking about electricity. For clarity, when the term is capitalized, it is referring to a specific market product; when it is not, the word is meant in its generic form.

5 CAISO and ERCOT price energy every 15-minutes; ISO-NE, NYISO, and PJM price energy every 5 minutes.

(over 12 MW) a Wind Output Limit every five minutes that represents the maximum amount a wind farm is allowed to produce[6] (NYISO 2010). Under normal operation this value will be equal to the maximum capacity of the wind farm; but in situations where wind needs to be curtailed, NYISO will lower this output limit for individual farms. The VERs subject to that constraint are economically dispatched based on their bids and the most expensive VER is decommitted until the constraint is resolved.

Settlements
The Energy market (and the consequent production tax credit for wind) is the main source of revenue for renewable generation owners and the detailed rules associated with their settlements can be the difference between a profitable market and one that does not deserve the investment.

Generation is compensated in the energy market based on the amount of megawatt-hours it produces. However, if the generator significantly over produces or under produces, the ISO has means to only compensate the generator for what it was supposed to produce or penalize the generator for not producing to its schedule.[7] On this issue there is a wide variation between ISO's on how to handle over/under generation. The Midwest ISO exempts VERs from any penalties as long as the deviation from the schedule is due to variations in wind and due to no fault of the operator[8] (MISO 2010). This essentially means that a wind farm will get paid for what ever it produces, regardless of the forecast accuracy.

By contrast, the NYISO will not compensate VERs for any generation above its forecasted level plus three percent.[9] If the VER generates less than its forecast schedule then it needs to pay for that missing generation at the real-time price of energy[10] (NYISO 2010). This gives the wind farm significant incentive to have an accurate wind forecast, especially if it is participating in the day-ahead market.

As the penetration of VERs increases, it is expected that many of theses rules will need to be revised to be more restrictive and give VERs more incentive to produce to schedule, reduce their variability, and reduce their ramp-rates.

---

[6] The signal is scheduled through NYISO's Real-Time Distpatch algority (RTD) which produces new solutions every five minutes. See section 2.23 of NYISO Market Services Tariff, sheet 66.

[7] For example, if a generator was scheduled to provide only 50 MW of its 100 MW rated generation capacity, the operator might have an incentive to produce an extra 50 MW and get paid more. Over generation penalties would generally charge the producer enough money to make producing only 50MW the optimal economic strategy.

[8] Section 40.3.4.d.i) Treatment of Intermittent resources, Sheet 1141

[9] Section 2.3 of NYISO Market Services Tariff, sheet 22

[10] Section 4.5.3 and 4.5.6 of NYISO Market Services Tariff, Sheets 121 a 126 respectively

2) **Ancillary Services**

There are five ancillary services that serve to ensure the reliable delivery of Energy as defined by FERC's *pro forma* OATT.[11]

- Scheduling and Dispatch: These are the services of scheduling generation resources before hand followed by the real-time control of generation and transmission resources that had been previously scheduled.
- Regulation and Frequency Response: resources adjust their output up or down to balance supply and demand over short time intervals
- Spinning Reserve: resources are 'on-call' and ready to increase their generation, or reduce their load, within ten minutes in response to a contingency event such as a loss of a generator or the loss of a transmission line.
- Supplemental Reserve: (similar to 10-minute Reserve but within 30 minutes).
- Voltage Support: resources inject or withdraw reactive power at a specific location in order support the transmission line voltage

Additionally, ISO's often consider the ability for generators to "Black-Start" as an ancillary service.

Of these, only Regulation, Spinning Reserve, and Supplemental Reserve are bought and sold through an open bid market. The responsibility of scheduling and dispatching falls on the ISO and voltage support and Black-Start are done through individual contracts between the ISO and suppliers based on the ISO's reliability and planning studies (Kirby 2007).

Due to the intermittent nature of renewable generation, ISOs do not allow VERs to provide Ancillary Services, although some have argued that given accurate forecasting and the ability to control a wind farm's output by feathering the blades, a wind farm could be able to provide Regulation or reserve products.

3) **Capacity**

The last product is Capacity, or ability to produce electricity. In order to understand what function a Capacity market is designed to serve, let us first consider what happens in markets that do not have a Capacity Market.

The price of energy, like the price of any other good, depends on the availability of supply and the amount of demand. On a short-term basis, the supply of energy is relatively fixed (it is not like someone can build a new power plant over night) and therefore people often think of demand driving the price of energy. On hot summer days when everyone has the air conditioners on, the demand for electricity is high and therefore the price of electricity is high. These times of peak consumption and peak pricing should send a price signal to energy suppliers to invest in more generation. This is the 'Energy-Only' approach taken by ERCOT. Historically, however, the infrequent spikes in pricing have not always been enough to drive investment. As a result, the ISOs have designed Capacity markets to provide long-term market signals for the investment into generation.

[11] These services are defined in section 3 of FERC *Pro Forma* Open Access Transmission Tariff, pg 26.

A Capacity market usually takes the form of a multi-staged incremental auction where participants bid to either produce or procure power. The ISO establishes a monthly price for Capacity, which is paid to the generation owner during respective delivery year. The generator is then required to be available to provide that Capacity, by the delivery year, on request during periods of peak demand; and there are stiff penalties for not delivering (although enforcement has been inconsistent). Most capacity markets require Capacity resources ensure deliverability by purchasing injection rights[12] and by bidding into the Day Ahead market to ensure their availability.

Offer Amount
A traditional generator could, if it desired, bid its entire operating capacity into the Capacity market and it will be expected to provide all that power during peak periods. This is also the case for VERs in some markets.[13] Other markets limit the amount of Capacity VERs can offer due to the fact that VERs are less dependable than traditional resources and therefore less likely to be able to provide Capacity when it is needed. For example, PJM limits VERs from offering more than can be proven to be available from four years worth of data. New units are limited based on similar resources already in the market (PJM 2010). For VERs, this is usually small fraction of their nameplate capacity.

Day-Ahead Energy Requirement
Another key aspect of a Capacity market is that most require Capacity resources to bid into the Day-Ahead market. The reasoning behind this is based on the fact that the Capacity market is only effective if it reduces extremely high prices during peak demand by sending the appropriate long-term price signal for investment into generation capacity. If a resource that is being paid to be a capacity resource doesn't bid into the day-ahead market, then it is likely that prices will still be extremely high and volatile.

VERs are often excused from these "*must-offer*" requirements as long as they are not viewed as trying to manipulate the market.[14] VERs are excused from this requirement because if they weren't, they would be required to be scheduled for their forecasted amount and required to be scheduled for at least the amount of expected delivered capacity. These two values could be different and could put the VER in an impossible position.

Penalty for Undelivered Capacity
Penalties for undelivered capacity are meant to deter companies from receiving payments for but not delivering Capacity. VERs, especially wind resources[15], produce only a fraction of their nameplate rating at peak times, when delivery of Capacity is measured. A VER that bids too much of their resource into the Capacity market faces severe penalties. The first of which is based on the size and duration of the deficiency as well as the value of that Capacity in that delivery year. The second of which is that the resources Capacity rating can be lowered to reflect its performance, which results in lower future

---

12 Injection rights are purchased by paying for any necessary transmission upgrades needed to guarantee the resource's ability to deliver the capacity.

13 NYISO Market Services Tariff 5.12.11.4, sheet 194;

14 NYISO Market Services Tariff 5.12.11.4, sheet 194;
MISO OATT 69.5, sheet 1490Z

15 Wind speeds, and therefore wind farm output tend to be non-coincidental with peak demand

capacity ratings and loss of injection rights for the amount of deficient energy[16] (PJM 2010). If the resource wants to re-qualify at the original Capacity value, they would have to again pay for any transmission upgrades associated with delivering that Capacity. The net result is that many VER operators only bid a small portion of their resource into the Capacity market, which can make an ISO's bidding limitations ineffective or unnecessary.

Conclusion:

The deregulated electricity markets have made a number of rules that apply specifically to renewable generation technologies in an effort to address their inherent intermittency and variability. These rules have allowed renewable technologies to reliably interconnect to the transmission network as well as participate in the Energy and Capacity markets. Given these rules, renewable generation has been reliably producing electricity. At higher penetration of renewable generation, however, these rules will need to be reevaluated to ensure that the underlying assumptions are still valid. For example, is a renewable megawatt-hour really equal in value to one produced from fossil fuels? Today, it is assumed that those two types of megawatt-hours are equivalent and the energy market prices them equally. At higher penetrations of renewable generation, there might be a significant cost to addressing variability of a renewable megawatt-hour and would therefore make a renewable megawatt-hour less valuable. As America moves towards a significant amount of renewable generation the market rules will have to be continuously reviewed to ensure that the market continues to select the least-cost reliable solution.

Acronyms and Definitions:

- CAISO: California Independent System Operator
- ERCOT: Electric Reliability Council of Texas
- FERC: Federal Energy Regulatory Commission
- ISO: Independent System Operator
- ISO-NE: Independent System Operator of New England
- LVRT: Low Voltage Ride-Through
- LGIP: Large Generator Interconnection Procedure – part of FERC's *pro forma* market design; OATT attachment X.
- MISO: Midwest Independent System Operator
- NERC: North American Electric Reliability Council
- NREL: National Renewable Energy Laboratory
- NYISO: New York Independent System Operator
- OATT: Open Access Transmission Tariff
- PJM: PJM Interconnection – It used to stand for "Pennsylvania-Jersey-Maryland" but now incorporates many more states than just those three.
- RTO: Regional Transmission Operator
- RTD: Real-Time Dispatch, the name of a scheduling algorithm in NYISO.
- VER: Variable Energy Resource

[16] For example of this see PJM manual 18

References:

FERC (2005). Interconnection for Wind Energy. 111 FERC ¶ 61,353. F. E. R. Commission. FERC eLibrary, FERC. **Order No. 661**.

FERC (2005). Order 661-A: Rehearing and Clarification on Interconnection of Wind Energy. 113 FERC ¶ 61,254. F. E. R. Commission. FERC eLibrary, FERC. **Order 661-A; Docket No. RM05-4-001:** 59.

FERC (2007). Preventing Undue Discrimination and Preference in Transmission Service. 118 FERC ¶ 61,119. F. E. R. Commission. FERC eLibrary. **Order 890; Docket No. RM05-17-000 and RM05-25-000**.

FERC (2010). Notice of Inquiry: Integration of Variable Energy Resources. 130 FERC ¶ 61,053. FERC Online, Federal Energy Regulatory Commission. **RM10-11-000**.

Kirby, B. (2007). Ancillary Services: Technical and Commercial Insights, Wartsila.

MISO (2010). MISO Open Access Transmission Tariff. M. I. S. Operator. www.midwestiso.org, MISO.

NREL (2008). 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply. Golden, CO, National Renewable Energy Laboratory**:** 248 pp.

NYISO (2010). NYISO Market Services Tariff. N. Y. I. S. Operator. http://www.nyiso.com/, NYISO.

PJM (2010). PJM Manual 18: PJM Capacity Market. PJM. www.pjm.com.

PJM (2010). PJM Open Access Transmission Tariff. PJM, PJM.