WHITEPAPER

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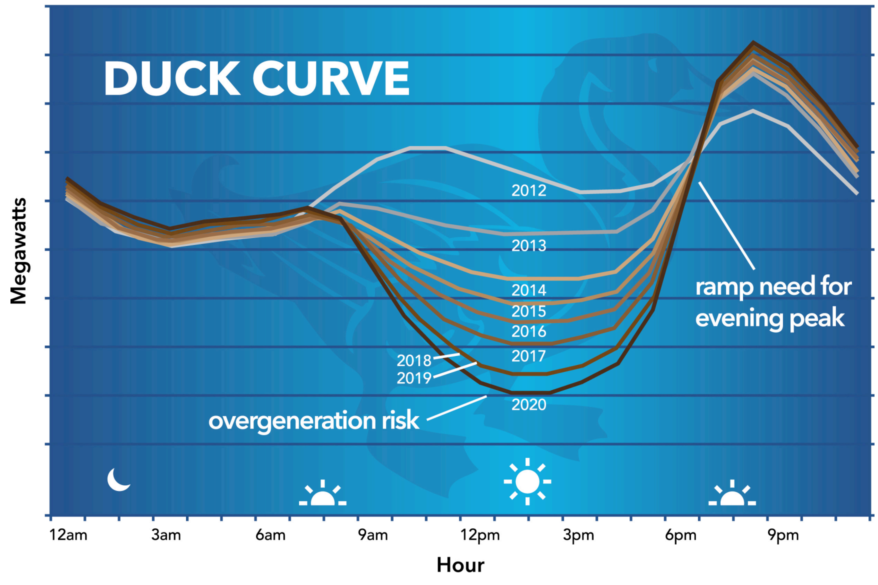
A Market Solution to the Duck Curve

I. INTRODUCTION

In the operation of today's power systems, renewables (especially solar and wind) are becoming a larger and larger part of the generation mix. While renewables are desirable for their low variable costs and for their low environmental impact, they can and do cause problems in day-to-day system operations. The most notable of these is illustrated by the "duck curve" where renewable outputs offset demand producing a "duck's belly" during normal maximum load periods as shown in the figure below and then cause higher than normal ramping needs when the sun goes down ("duck's head").



This sudden and sustained decrease in apparent demand and high ramping requirements that conventional resources currently supply can cause over-generation and regulation issues. A number of solutions have been suggested to cope with this problem including greater grid integration, greater use of storage techniques, demand management, demand response, efficient use of peaking resources and efficient use of resources that have high regulation ability. Often, it is suggested to use regulatory and artificial pricing schemes to achieve these solutions. However, a market solution is also feasible and certainly preferable. Regulatory schemes are slow to change; properly designed market solutions evolve and adapt as the environment and market changes.

It should be noted that the problem is not how to flatten the curve, but rather how to deal with it. The "duck curve" will never go away. In fact the belly of the curve will grow larger as renewables become a greater and greater part of the resource mix. The real challenge is how to deal with the problems created by this curve: over-generation and high ramping requirements and increased regulation.

II. Grid Interconnection vs. Grid Coordination

One solution suggested for dealing with the problems caused by the "duck's belly" is expanded grid interconnection. The idea behind this is that a larger interconnection will spread out the load and resources (including renewables), which should tend to flatten the curve. However, the North American grid is already tightly integrated into the Eastern and Western Interconnections. The only exceptions are Hydro Quebec and ERCOT. These two systems are connected to the rest of the interconnection through DC ties, but are not synchronized to the rest of the system.

The real solution is not greater interconnection, but greater *coordination.* Both the Eastern and Western Interconnections include both market based systems and "old-world" systems that are still heavily regulated and vertically integrated. The Eastern Interconnection is essentially market based with systems such as the MISO, PJM, NYISO, and ISO-NE, although it also includes vertically

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integrated and regulated systems such as TVA and Duke. Currently, the only market-based system in the west is CAISO. However, CAISO has developed a market-based Energy Imbalance Market (EIM), which will soon expand into other western systems.

Market-based systems encourage coordination and cooperation among systems, since they give each the ability to buy and sell resources across borders to most economically serve multi-regional load. In addition, many of these systems have developed means to coordinate inter-system transactions (Coordinated Transaction Scheduling, or “CTS”), in order to expand the pool of available resources (Market-to-Market dispatch or “M2M”) among them. This expanded coordination can help each system deal with the ramping and over-generation issues created by renewables. For example, consider system “A” with a large amount of renewable resources, but relatively little in the way of dispatchable resources. Meanwhile, a neighboring system “B” has a large amount of quick responding and dispatchable hydro generation. As system “A” enters and exists the belly of the duck, system “B” can provide the ramping and regulation required to cope with large load swings. During periods of over-generation in “A”, “B” could absorb the excess through ponding and pump storage, which could then be sold during peak periods. In a market-based system, this would all be accomplished through a set of economic transactions. Both systems would benefit. Note that this could be implemented through a set of two-party agreements and transactions between the systems, but would not be as spontaneous or economical as the market could provide.

III. Current Market-Based Solutions to Renewable Integration

Solutions other than expanded grid integration have been offered to solve the “duck curve” problems created by renewable integration. These include, but are not limited to: expanded regulation and load following capability, resource management, and demand management. Any of these solutions can be achieved economically with a market-based system as described below.

Ramp (Regulation and Load Following): A Valuable Commodity in a Renewable World

Regulation is the ability for a generator, and a system, to rapidly respond to frequency deviations on a second-to-second basis. Load following is the ability for a generator, and a system, to rapidly respond to load deviations, generally on a minute-to-minute basis (most real-time markets provide load following on a 5-minute basis). As more and more renewables are integrated into a system, the regulation load following requirements of the system as a whole increase while capability may decrease. Two factors cause this: First, solar and wind usually lack the ability regulate and/or follow load (and may, in fact, impose additional regulation and load following burdens on the system); Second, renewables displace older, inefficient steam resources that had some ability to regulate and/or load follow. In order to provide sufficient regulation and load following as renewables are integrated, two things should occur: renewable resources should be developed to include regulation and load following capability and incentive should be provided to existing resources and technologies to provide more regulation and load following to the system.

Developing renewable resources that have regulation and load following capability will require improvements in existing technologies. Some wind turbines today are being developed with variable-pitch blades. With this technology, wind turbines would have the ability to incrementally increase or decrease output and provide regulation and load following. Solar can vary output by switching individual panels in or out. However, in order to give solar regulating and load following ability, the panels would need to be small enough to effect incremental output changes. This would require and increase in number of panels, switching units, and associated controls substantially increasing installation and operating costs. In addition, both wind and solar would require Automatic Generation Controls (AGCs) in order to follow frequency (regulation), but these controls would not be required to provide load following.

Steam and hydro resources will continue to provide regulation and load following, as they do today, but the service will become more valuable. More on the compensation to regulation resources will be discussed shortly (compensation for load following is generally in the form of payment for energy output every 5 minutes, but some markets are considering separate compensation for a ramp product other than regulation). Other newer technologies that can provide regulation are batteries and flywheels. Batteries generally charge (sink power) when energy prices are low and inject into the system when prices are high. Similar to pumped storage, they are generally used as a peaking resource. Flywheels are installed specifically as a regulating resource. Energy is absorbed when frequency is high, and injected back into the system when frequency is low. The resource is charged or paid for energy at its but locational marginal price (LMP). Flywheels have been installed and operated in the Eastern Interconnection (NYISO and PJM), and have operated profitably.

As with energy, regulation can be transacted from one system to another. For example, in the west CAISO has a large amount of renewables, with the associated decrease in regulating ability. Meanwhile, the northwest is blessed with large amounts of hydro. While hydro is valued for its cheap and clean energy, it also has the ability to respond very quickly to changes in demand and is a great sources of regulation (and load following). In a properly designed market, regulation would be sold from the northwest to CAISO during periods of high renewable output (the bottom of the "duck's belly"). In effect, the northwest would be compensated for its high ramp ability.

Compensation for Regulation and Cost Recovery

How are regulating resources compensated? In a deregulated market, energy is not the only product resources are compensated for. Resources also produce, and are paid for, ancillary services such as regulation, reserve, and voltage support. Regulation is the most valuable of the ancillary services, and resources are paid for both regulating capability and the amount of regulation actually provided (movement). If a unit is dispatched to provide regulation in lieu of energy, it is also compensated for any lost opportunity cost. As noted above, flywheels have been installed solely to provide regulation and have proven to be profitable. Energy or absorbed by a flywheel is paid or charged at bus LMP.

Generally, the cost of regulation is recovered by parties that cause a regulation burden, according to the cost causation principle. Load is continuously variable, and is the largest cause for deviations requiring regulation; hence the load bears the largest share of the regulation cost. Generation that fails to follow a schedule or varies from dispatch by a set amount also causes deviations and would bear a share of the regulation cost. Also, regulating units that fail to provide required regulation would bean a share of the cost (this is true for most markets, SPP charges all regulation cost to load).

What about wind and solar? Except for areas of steady, predictable wind or near constant sunshine, these renewables are difficult to predict and may be sporadic. Therefore, unless they can self-supply, an argument can be made that renewables should bear some of the regulation cost since they create a regulation burden.

Resource Management

Power systems are already familiar with the concept of resource management. Its most common use is to shift the output of energy-limited resources, such as pump storage-generators or combustion turbines, from low to normal load periods to high load periods. In a market-based system, prices will generally dictate when resource owners should schedule energy-limited units to take advantage of high-price periods. Renewable resources will create a new paradigm for owners of energy-limited resources. Resources may no longer be required during the morning load increase as renewables come on-line. However, they will still be needed during the evening peak as solar units come off-line as the evening load increases. A combination of loss of renewable energy and load increase may cause prices to spike higher than they do today during the evening peak, especially during the winter months.

Another resource management method involves hydro scheduling. For example, during daytime periods of high renewable injection in CAISO, there is a very real danger of over-generation, resulting in low or possibly negative prices. The northwest could then buy energy from CAISO at the low prices and pond water and/or operate pump/storage facilities in pump mode. During the evening peak, the northwest would sell power back to the CAISO at a high price. In addition, during periods of over-generation or rapid load increase, regulation becomes scarce with resulting high scarcity prices. There may be an attractive market for the northwest to sell regulation to the CAISO.

A final source of resource management is storage. Proven and existing sources are pump/generating hydro units, which are expensive and require a large tract of land to develop. Other developing sources include battery technology and compressed air. These technologies are currently in their infancies and expensive, but with innovation and increased future demand will become more practical in the future.

Demand Management

In a market-based system, demand management will occur as load responds to prices. Wholesale load, such as load aggregators and agricultural pumps, should respond to price signals at their bus. At the retail level, consumers can program devices such as water heaters and air conditioners to decrease usage during high price periods. However, some type of price signal would need to be transmitted to the customer. With the advent of smart metering, this is entirely feasible.

IV. A Word About Cost and Bidding

In a well-designed and competitive market system, resources will bid in very near or at actual variable production cost. For steam units, this will be essentially fuel cost. Hydro units have a near-zero fuel cost and generally bid as such. However, water or other restrictions may cause the resource to vary bids in order to limit output during certain periods.

What about wind and solar? Like hydro, the fuel cost is zero. As a result, these resources generally bid in at zero cost. Resources that receive a government subsidy based on output may actually bid in at negative cost. Units with zero or negative cost are generally scheduled as must-run. During over-generation periods, the LMP may go to zero or below in an attempt to force these units off-line. Units that remain on-line will pay to generate (and load will be paid). With subsidies, it may be advantageous for a renewable unit to remain on-line, thwarting the attempts of the market system to reduce generation. At this point, system operators will order these units off-line due to an actual or potential high frequency situation.

Note that in all market systems, an independent Market Monitoring Unit (MMU) is required by FERC to oversee operation of the market. One of the responsibilities of the MMU is to oversee bidding and the resultant prices. Abnormally high or low bidding strategies must be justified.

V. Conclusion

In a well-designed market-based integrated system, there is no need for regulatory dictates or artificial pricing schemes to accommodate renewable resources. With a large enough interconnected grid where most of the parties participate in a market-based system, trade is facilitated and required products (energy and regulation) will be available as needed at an appropriate market price. Inefficient units will be phased out, replaced by cleaner and lower cost energy. Any detrimental effects caused by the must-take and sporadic nature of renewables will be offset by a robust and profitable market in new and clean sources of storage and regulation. In a well-designed market system, regulatory requirements, and artificial pricing schemes should not be required to encourage growth of a clean and efficient renewable market.

ABOUT UTILICAST

Utilicast is a premier management, regulatory, and solutions consulting firm that specializes in the electric utility industry. Our consultants deliver a powerful combination of experience, management, and subject matter expertise in markets, system operations, compliance, metering, retail and other industry areas. Since 2000, we have provided our customers with an expert level of service that brings results from both a business practices and information technology perspective. Our experience spans the entire U.S. region, as well as several international entities.

ABOUT RICK HOEFER

Rick specializes in Market Design, especially in areas related to Operations and Settlements. Rick was instrumental in the development of the original NYISO market-based system and NYISO's Standard Market Design 2 (SMD2) settlement rules and Tariff language. Rick was also involved in the development of MISO's Ancillary Service Market. Rick has experience in the NYISO, PJM, MISO, CAISO, SPP and developing western markets. You may contact Rick at: rhoefer@utilicast.com.