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Energy Storage and Ancillary Services Markets in North America

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SUMMARY

Ancillary services are critical to maintaining the operational reliability of interconnected power systems. Since the transformation from vertically integrated power systems towards competitive electricity markets in North America, the procurement of these services have been defined and designed to achieve efficient and competitive ancillary services markets and enhance the system reliability.

This paper reviews the ancillary service provisions, focusing mainly on operating reserves and regulation, in the North American (US and Canada) electricity markets. Since the definition of each of the considered ancillary services differs from one market to another, this paper highlights the main differences between these services. The ancillary services market structure, procurement process, and deployment timeline is also discussed.

Energy storage systems (ESS) have the potential to improve the efficiency of ancillary service markets and enhance system reliability. This paper presents the key advantages of ESS in the provision of ancillary services in these markets, and identifies their limitations, such as their life cycle and limited energy in terms of state of charge.

In this paper, the changes in the regulation markets after implementation of the *pay-for-performance* concept, to comply with Federal Energy Regulatory Commission (FERC) Order 755, and how it allows more participation of resources such as ESS in ancillary service provisions is discussed. In the near future, ancillary service markets are expected to develop new pricing mechanisms, allowing further participation of ESS and removing the barriers that are limiting their competition with traditional resources, to comply with the recent FERC Order 841, issued in 2018. A brief review of the anticipated changes in the ancillary services markets is presented.

KEYWORDS

Energy storage – Ancillary services – Reserve market – Regulation market

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1. INTRODUCTION

The North American Electric Reliability Council (NERC) has defined ancillary services as "elementary 'reliability building blocks' from generation (and sometimes loads) that are necessary to maintain the bulk electric system reliability". These services are: (1) regulation (2) load following (3) contingency reserve (spinning and supplemental) (4) reactive power supply from generation sources (5) frequency response and (6) system black start capability [1].

Most of these services are procured on a cost basis and contractual agreements. However, the frequency regulation, spinning and non-spinning reserves are procured through a competitive settlement based market environment, which are the main focus of discussion in this paper.

2. REVIEW OF MARKET-BASED ANCILLARY SERVICES

The ancillary services in North America are procured through cost-based contracts with the exception of frequency regulation and operating reserves. It is noted that regulation and reserves are interchangeable terms across different markets, and hence it is important to distinguish these services and their definitions. Both of these services are crucial to maintain the supply-demand balance activated in different time frames to ensure the frequency of the system to be within the acceptable limits.

In power systems, the frequency control hierarchical structure comprises three levels: primary, secondary, and tertiary frequency control [2]. Primary frequency control is commonly known as "frequency response", and it is the local automatic control which adjust the active power automatically within milliseconds following sudden and large generation or load outages. The main objective of primary control is to stabilize the frequency, without the need to resume to the normal set point. Secondary frequency control is commonly known as "frequency regulation", and seeks to maintain the balance, in a time-frame ranging from seconds to a few minutes, by injecting/drawing active power, following the automatic generation control (AGC) signal. The main goal of secondary control is to restore the frequency to its nominal value. The third level is tertiary frequency control which is activated within 10-30 minutes, following the event, to manually change the unit commitment dispatch.

In North America, the primary frequency control service is procured through contracts, while secondary and tertiary control are mostly procured through a market based system. Although some of the markets refer to frequency regulation as the operating reserve, in this paper, the term operating reserve will be used for the contingency reserve which can be divided into spinning, non-spinning and replacement/supplemental reserves.

3. ENERGY STORAGE SYSTEMS AS ANCILLARY SERVICE PROVIDERS

3.1 Values and Challenges of ESS Ancillary Service Provisions

The ancillary service markets have been more active with the recent trend of increasing share of renewable energy sources (RES) in the generation mix, such as photovoltaic and wind generation. These resources are not dispatchable and when there is excess energy supply during off-peak hours, RES curtailment is required to maintain the demand-supply balance. In this environment, ESS play a pivotal role in facilitating the integration of RES to mitigate the aforementioned issues.

ESS are characterized by their fast response time and high ramping capability, which are crucial features in ancillary service provisions to maintain the demand-supply balance effectively. Furthermore, ESS can operate as a generator (during discharging) and a load (when charging), allowing them to provide regulation and reserve services in both directions.

However, ESS have different operational and physical characteristics, as compared to the traditional ancillary service providers. Unlike electrical generators, ESS are also specified by their energy storage capacity in addition to their power rating or size. The power size of an

ESS is defined as the rate at which the ESS is capable of discharging/charging power continually. In normal operation, the maximum injected/drawn power is the nameplate rating of the ESS. The energy size represents the maximum amount of energy that can be stored. Therefore, ESS is also characterized by their discharge time, which is the maximum duration for which the ESS can discharge at rated power. It is to be noted that the discharge time depends on the available energy which is known as the state of charge (SOC) level of the ESS.

Furthermore, most ESS suffer from degradation which affects their performance and reduces their lifetime. Three major factors affect the ESS lifetime, and whenever one of them reaches its limit, the ESS should be replaced: calendar lifetime, number of charging and discharging cycles, and the total discharged energy. To reduce the impact of degradation, the operation of the ESS should be controlled, in order to increase its benefits at least cost. For example, the ESS may not be allowed to discharge below a certain level of its energy capacity. The maximum discharge limit is expressed as the depth of discharge (DOD) of the ESS.

Because of these characteristics, it is challenging for ESS to compete in the ancillary service markets that have been designed traditionally considering the conventional resources. Furthermore, the high capital cost of ESS is another factor that limits investing in ESS. Therefore, there is a need for new operational and regulatory frameworks to integrate ESS to existing market clearing models. There is also a need for appropriate incentives for ESS investors to achieve an efficient ancillary service market and facilitate higher penetration of RES.

3.2 Current Regulations and Policies

In order to accommodate ESS participation effectively in the electricity markets, the US Federal Energy Regulatory Commission (FERC) has issued some policies to remove the barriers that are limiting their competition with traditional resources. FERC Order 755, issued in 2011 [3], is one of the key policies that has paved the way for ESS to participate in regulation markets and consequently the frequency regulation markets in US are being redesigned following Order 755 to improve the performance of regulation providers in tracking the AGC signal.

The performance based regulation (PBR) market considers in their pricing mechanism the speed of response and the accuracy of following the operator signal. Therefore, a participant in the PBR market receives two-part payments: the traditional regulation capacity payment, and a new performance payment for the actual quantity of regulation power provision, referred to as *mileage*. The *regulation capacity* can be defined as: "the reserved capacity of a unit to provide regulation power during a determined period of time". The *regulation mileage* is an index to measure the performance of a regulation provider, and can be defined as: "the sum of absolute movements towards the set point of the regulation signal".

Figure 1 shows an example of the set point of the regulation signal and the mileage scored by a resource. It is noted that the performance payment (R) differs from one market to another, but generally is computed after real-time operations, as follows:

$$R = (\bar{M}) \times (M) \times (P_{Score})$$

Where, $\bar{M}$ is the Mileage Offer in \$/MW, M is the Mileage in MW and P_{Score} is the Performance Score in %, is a factor representing the accuracy of the regulation provision. It is noted that the regulation capacity and mileage settlements take place simultaneously in the day-ahead and/or in the real-time market.

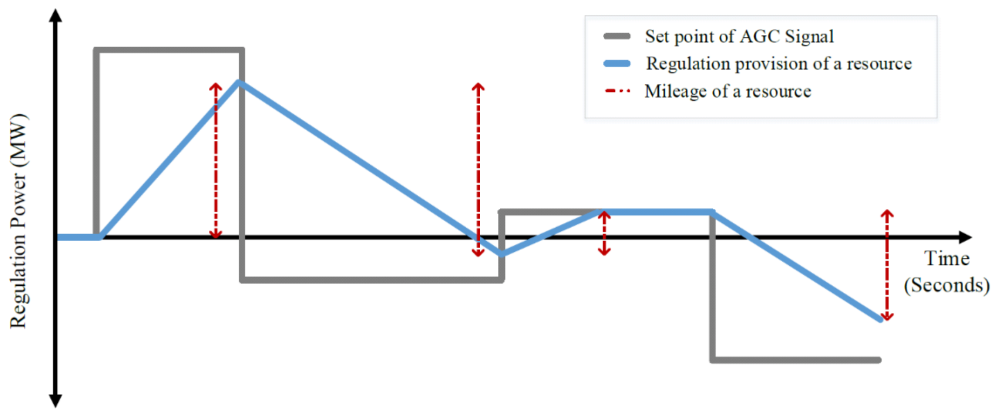

Figure 1. Regulation mileage definition

Subsequently, FERC Order 841, issued in 2018 [4], focused on ESS to participate side-by-side with other traditional market participants by considering their physical and operational characteristics in the capacity, energy, and ancillary services markets. One of the main changes in markets under FERC will be to consider bidding parameters in the market settlement structure representing the ESS characteristics, such as SOC, SOC limits, charge and discharge time, charge and discharge limits, charge and discharge ramp rates, and run time limits. Furthermore, ESS with a minimum capacity of 100 kW will be allowed to participate in all the markets, whereas currently most markets require at least 1 MW of capacity. Also, after implementing FERC Order 841, ESS should be able to set the market clearing prices as both wholesale buyer and seller, and de-rating of the ESS capacity will be considered in the markets, which the help of ESS to meet the minimum run time requirements.

4. ANCILLARY SERVICES MARKETS IN NORTH AMERICA

4.1 PJM Market

The electricity market operated by PJM is one of the US markets under FERC jurisdictions. In PJM, the installed capacity of ESS is more than 278 MW and 269 MWh, mostly from battery storage systems, which is considered as one of the largest ESS market capacities in North America [5]. PJM has two categories of ESS: energy storage resources (ESR) which includes batteries and flywheels, and capacity storage resources (CSR), which in addition to ESR includes hydroelectric plants. Both the operating reserves and frequency regulation are procured through a market-based system.

The operating reserves in PJM is defined as the amount of power that can be received within specific time from synchronized or offline generators and certain loads. The operating reserves are categorized into: primary reserve, which can be received within 10 minutes, and supplemental reserve which can be available within 30 minutes. The primary reserve is divided into synchronized and quick start reserves based on the status of the resource. Currently, ESS are not eligible to participate in non-synchronized reserve provision. Although ESS are allowed to participate in synchronized reserve provision, allocating ESS capacities to participate in regulation markets is more profitable for ESS investors.

In the PJM regulation market, the providers are instructed to adjust their generation or demand in response to an automated signal to maintain the area control error (ACE) within its limit. To comply with FERC Order 755, PJM generates two types of signals: RegA and RegD, and the regulation providers can choose to follow either one. RegA is a low-pass filtered signal to recover large and long fluctuations, and designed for slow resources, whereas RegD is a high-pass filtered signal requiring instantaneous response from fast resources. Furthermore, RegD signal is designed to be zero-mean energy within 15 minutes period, which allows ESS to maintain their SOC level after the regulation provisions.

The regulation providers are required to submit a two-part offers, capacity (capability) offer in ($/MW) and performance offer in ($/ΔMW). The mileage is defined in PJM as "the summation of movement requested by the regulation control signal a resource is following" [6], and is formulated as follows:

$$Mileage_{RegA} = \sum_{t=0}^{T} |RegA_t - RegA_{t-1}| \quad Mileage_{RegD} = \sum_{t=0}^{T} |RegD_t - RegD_{t-1}|$$

The regulation compensation is based on the adjusted costs, as follows:

$$Adjusted\ Regulating\ Capability\ Cost\ [\$] = \frac{\alpha\ [\frac{\$}{MW}]\ C\ [MW]}{\pi\ \rho}$$

$$Adjusted\ Performance\ Cost\ [\$] = \frac{\beta\ [\frac{\$}{\Delta MW}]\ M\ [\frac{\Delta MW}{MW}]\ C\ [MW]}{\pi\ \rho}$$

where α and β are the capability and performance offers, respectively, while C and M are the capability and mileage quantities, respectively. The benefit factor (π) of RegD is 3 times RegA, and the historic performance score (ρ) is a factor averaged over 30 day of a resource representing the performance in following one type of regulation signals.

4.2 California Independent System Operator (CAISO)

CAISO is the first system operator in North America that procured ancillary services through a competitive market settlements, and has one of the largest ESS market capacity of about 130 MW and 381 MWh [5]. ESS can offer and bid as non-generator resources "NGR" in day-ahead energy, reserve markets, and regulation markets.

There are three types of operating reserves in CAISO are spinning, non- spinning, and replacement reserves. The spinning reserves is defined as: "generation that is already up and running, or "spinning," with additional capacity that is capable of ramping over a specified range within 10 minutes and running for at least two hours", while the non-spinning reserve is "generation that is available but not running, that is capable of being synchronized and ramping to a specified level within 10 minutes, and then capable of running for at least two hours.". The replacement reserves on the other hand is "generation that is capable of starting up if not already operating, synchronizing with the ISO controlled grid and ramping to a specified load within one hour, and running for at least two hours" [7].

The regulation market in CAISO is split into regulation-up and regulation-down, and procured in day-ahead and real-time markets. The required hourly quantity in the day-ahead and the 15 minutes period in the real-time markets are determined based on the CAISO demand forecast for these services. CAISO co-optimizes the energy and ancillary services markets to determine the market clearing prices and the regulation capacity awards. The regulation provider receives regulation capacity payment, which includes the opportunity cost and payment for net energy, and mileage payment considering accuracy adjustment. The mileage is defined as: "the absolute change in AGC set points between 4 second intervals".

It is noted ESS participating as NGR can benefit from the regulation energy management (REM), which designed by CAISO for energy limited resources. While traditional non-REM units require 60 minutes continuous energy, REM units require only 15 minutes of continuous energy, and hence allowing ESS to offer higher regulation capacities. For example, for an ESS with 20 MW and 5 MWh, participating under REM allows it to offer 20 MW of capacity for the 15 minutes duration, while it can only offer 5 MW of capacity for 60 minutes because of the limited SOC. Furthermore, units participating under REM can submit preferred level of SOC, and hence after the regulation provision, the ESS is compensated from the next interval in the real-time energy market to maintain the level of SOC. It is noted that REM units can only participate in regulation markets.

4.3 New York Independent System Operator (NYISO)

The ancillary services are classified into: regulation, operating reserve, and energy imbalance, which are procured through market-based pricing. ESS can participate in the NYISO markets under one of the following categories: energy limited resources, limited energy storage resources, demand side ancillary service, and special case resource [8].

The operating reserves in NYISO are classified as: 10-minute spinning reserve, 10-minute non-synchronized reserve, 30-minute spinning reserve, and 30-minute non-synchronized reserve. ESS can participate in operating reserve as energy limited resources, however it must be able to provide at least 1 MW of continuous power for 4 consecutive hours without aggregating with other units. ESS can also participate in reserve provision under the demand side ancillary service program and special case resource with the possibility of aggregating the required minimum capacity with other units.

The NYISO regulation markets is a performance based market where a participant submits a capacity bid and regulation movement bid, both in ($/MW). The regulation provision is procured through day-ahead and real-time markets. ESS participating in the regulation market under limited energy storage resources is managed by real-time dispatching (RTD) of NYISO, and the offered regulation capacity may be reduced if the available SOC in one of the directions, either charging or discharging, is less than the cleared offer. The RTD manages the SOC to maintain its level every 5-minute interval.

4.4 Midcontinent Independent System Operator (MISO)

MISO is the largest system operator in North America serving 15 states in the US and one province in Canada. The total installed capacity of ESS participating in MISO markets is 21 MW and 28 MWh [5]. In MISO, ESS can only participate in regulation markets.

The operating reserve in MISO is known as the contingency reserve and divided into spinning and supplemental reserves. The reserves are procured in day-ahead and real-time markets, on an hourly basis in both markets [9]. The regulation market in MISO is a two-part bidding structure with capacity and mileage bids. The mileage payment is received based on the movements as ΔMW every 4 seconds.

4.5 Independent System Operator of New England (ISO-NE)

The operating reserve in ISO-NE is procured in forward reserve market through auction clearing, and real-time reserve pricing is considered to offset lost opportunity costs if the reserve capacity is deployed. There are three types of reserves in ISO-NE: 10-minute spinning reserve, 10-minute non-spinning reserve, and 30-minute operating reserve. The frequency regulation is procured in a real-time market considering a performance score to comply with FERC requirements. The total installed capacity of ESS is 23 MW and 26 MWh [5]. Currently, ESS can only participate as a generator, load, or demand response resource.

4.6 Southwest Power Pool (SPP)

The market-based ancillary services in SPP includes regulation up, regulation down markets, spinning contingency reserves, and non-spinning contingency reserves. These are procured in day-ahead and real-time markets. Most of these services are provided by conventional resources.

4.7 Electric Reliability Council of Texas (ERCOT)

The electricity market operated by ERCOT is the only market in the US not regulated by FERC. The ancillary services, including responsive reserves, non-spinning reserve, replacement reserve, regulation-up, and regulation-down, are procured in a day-ahead market. Since ERCOT is not under FERC, there is no performance payment considered, however the performance of the resources are monitored in the regulation markets.

The total installed capacity of ESS is about 83 MW and 41 MWh [5], and ESS can participate in energy or ancillary services markets in ERCOT as generators with a minimum capacity of 1 MW.

4.8 The Independent Electricity System Operator (IESO) of Ontario, Canada

The electricity market operated by the IESO is one of the two markets in Canada. Four of the ancillary services namely: certified black start facilities, regulation service, reactive support and voltage control service, and reliability must-run are contracted, while only the operating reserves are procured through market-based system [10].

The operating reserve is defined as "stand-by power or demand reduction that can be called on with short notice to deal with an unexpected mismatch between generation and load". There are three classes of reserves in IESO: 10-minute synchronized (spinning) reserve, 10-minute non-synchronized (non-spinning) reserve, and 30-minute reserve (non-synchronized). The scheduling of operating reserve and energy in the real-time energy markets are co-optimized, and the reserve prices are determined every 5 minutes.

Currently, the IESO regulation market is based on contractual agreements, and the regulation provisions payments comprise fixed and variable costs. The regulation capacity requirements are fixed for all intervals. IESO requires ±100 MW of AGC scheduled at all times, with a minimum overall ramp rate requirement of 50 MW/minute. However, the scheduled regulation capacity will be increased to 150-200 MW by the end of 2019. And, additional "as-needed" regulation capacity will be scheduled by the end of 2020 to increase regulation capacity up to 300 MW.

The participation of ESS including flywheels and battery storage systems in regulation provisions was launched in 2012 as part of the alternate technologies for regulation pilot program. In 2013, the Ontario Long-Term Energy Plan had proposed initiatives to understand the value of energy storage systems in Ontario, which has resulted in procuring 50 MW of different types of energy storage through two phases, supporting several energy storage projects at the distribution level using Smart Grid Fund, and conducting studies highlighting the benefits of ESS [11]. To further integrate the ESS within the current structure of IESO, the Energy Storage Advisory Group is established in 2018.

The total ESS capacity in IESO markets is 105 MW. ESS participate in the provision of regulation, reactive support, and voltage control services. Phase I of the energy storage procurement framework (2014) has procured 32.8 MW of ESS to provide regulation, reactive support, and voltage control services including: 8 batteries (25.8 MW), flywheel (5 MW), Hydrogen-Gas Storage (2 MW). Furthermore, in 2017, the IESO has awarded contracts to two battery storage facilities (55 MW) to provide regulation services. It is noted that Phase II of the energy storage procurement framework has procured 16.75 MW of capacity to the grid (8 facilities including 15 MW of batteries, and one 1.75 MW of compressed air energy storage). As of now, ESS participation is limited to contractual agreements, and hence ESS cannot submit offers or bids in any of the IESO markets.

4.9 The Alberta Electric System Operator (AESO), Canada

The ancillary services in AESO are classified into: operating reserve, transmission must-run, black start, and load shed services for imports. The operating reserves are categorized as regulating, spinning and supplemental reserves. The regulating reserves instantaneously provide the power difference between supply and demand required during that lag period. Spinning and supplemental reserves, known as contingency reserves, are used to maintain the balance of supply and demand when an unexpected system event occurs. The operating reserves are procured through day-ahead market-based settlement, while other ancillary services are procured using contracts.

The ESS participation in AESO is still under study. A cost/benefit analysis was conducted by the AESO to assess the need of two main types of storage systems. First, Li-ion battery representing short-duration and low-energy ESS is considered, and second, pumped hydro storage is considered representing long-duration and high-energy ESS. It is shown that only Li-ion storage might be cost-effective in AESO because of the revenue from ancillary services markets. However, the ancillary services market in AESO is small, and hence, the market supports only a small amount of ESS until the market saturates.

5. CONCLUSIONS

In this paper, a review of the current ancillary service markets in North America is discussed focusing on the operating reserves and regulation markets, which are procured through market-based settlements. The participation of ESS in the ancillary service provisions are also discussed highlighting the current practices to accommodate these resources.

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