The Safe & Electrical Transmission for Energy Markets and Grid Technology

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ABSTRACT

Energy storage in grid applications ranges from distributed community energy storage (CES) to large, centralized, bulk storage. This paper focuses on four application areas: ancillary services, transmission services, CES and other distributed storage.

Ancillary services, renewable energy integration and transmission support are promising for near term growth while CES is most promising for long-term growth in grid energy storage. Near-term growth will come from past investments as well as the emergence of new policies to promote the market. The long-term market for storage will depend on the ability of suppliers to reduce costs and policies to help formalize application markets.

Industry analysts forecast that the global market for energy storage could increase to 300 GW with a value from $200-600 billion over the next 10 to 20 years. In the short term, the size of the U.S. grid energy storage market is forecast to reach between two to four gigawatts by 2017 [1]. According to a 2014 roadmap from the International Energy Agency, there is already more than two gigawatts of installed thermal storage capacity in the country [2].

Keywords: grid, energy, storage, copper, forecast

1 INTRODUCTION

The term "energy storage" could refer to many types of storage technologies, including electrochemical, mechanical, or thermal. For specifics on energy storage initiates and detailed analyses of the copper content projections, the reader is referred to the original DNV GL (formerly KEMA) study, which is currently available online from the Copper Development Association [1].

Energy storage technology is typically classified according to rated power and discharge duration. Together, these characteristics describe how much power a storage unit can provide (in MW) and for how long (in hours). Even within a given technology type, the range of ratings can be large and there is a great deal of overlap in technology ratings.

Initial investment, operating costs and service life all are factors in evaluating the cost of energy storage. These costs are related to performance, which is measured in terms of capacity, efficiency and cycle life. Cycle life refers to the number of charge and discharge cycles that a storage device can provide before efficiency decreases so as to make it no longer capable of suitably performing the functions it needs to in an application.

A report by Sandia National Laboratories identifies 19 different energy storage grid services [3]. Grid storage is connected along the electric grid system at various locations. It can range from distributed energy storage at the community scale, which is on the order of kilowatts (kW) in capacity; to large-scale battery energy storage, which is on the order of one or two megawatts. The latter can be aggregated up to 50 MW in size. Bulk grid storage can be on the order of tens of megawatts.

The growth potential for grid energy storage remains tremendous as predicted by an earlier study [1]. Aspirations for energy independence coupled with urgent needs to stabilize peak load times is driving the demand for energy storage systems. Growth will be fueled by investments as well as governmental policies and copper will play a significant role in this growth.

Copper contributes to safe, reliable and efficient transmission of electricity in all energy markets and grid technologies. Its superior electrical conductivity is essential for many electrical products and systems, including wires and cables as well as motors, generators, transformers and protective devices. Copper provides efficient transmission and distribution of electricity. It is ideal for electrical applications because it conducts electicity better than other commercial metals, i.e., it is 65 percent more conductive than aluminum. Copper keeps the power grid working efficiently because its electric and thermal properties minimize load loss.

2. GRID TECHNOLOGY

The applications having the largest near-term market growth include community energy services, ancillary services, renewables energy integration, transmission services and other distributed storage.

Community energy services (CES) consists of a small, distributed energy storage unit connected to secondary transformers serving a few houses or small commercial loads. As the name implies, local communities are the primary beneficiaries of an energy storage device. CES enhances reliability, reduces the required capital investment by flattening peak loads, compensates for the variability of distributed renewable resources, such as roof top solar photovoltaics (PV), and provides a source of back-up power during grid events for residential and commercial and industrial customers. As such, CES combine multiple applications to serve grid needs at the end of the distribution system.

"Ancillary services" are tools used by grid operators to help maintain a continued balance between electricity production and demand. Fast-response storage devices have the ability to provide frequency regulation and spinning reserve grid services, a subset of the full set of ancillary services. Independent system operators and regional transmission organizations (ISOs/RTOs) are currently examining the potential for fast-response storage devices to act as an alternative to traditional generation technologies to help balance system supply and demand through regulation and spinning reserves services.

"Transmission services" include the deferral of transmission and distribution equipment (also known as T&D deferral), transmission support, and transmission congestion. T&D deferral is the use of energy storage to defer the installation or upgrade of transmission and distribution equipment, which can often be difficult to site. Transmission support refers to the use of energy storage to address electrical anomalies and disturbances on the grid. Transmission congestion relief refers to the use of storage to avoid the need to transmit power during periods of high system demand; for example, energy stored by devices could be used during on-peak hours when the transmission systems are congested.

Increased implementation of variable renewable generation resources, especially wind and solar, may increase grid volatility, requiring an increased need for frequency regulation services. Advanced energy storage technologies with fast-response capabilities are a promising approach to managing the volatility of renewables.

The renewable energy integration application is directly linked to intermittent renewable implementation on the grid (e.g., wind and solar) and the amount that occurs on a percentage basis. Energy storage can address three "buffering" challenges that variable energy resources introduce on the grid system: 1) *Capacity firming*, as previously discussed under ancillary service/regulation; 2) *Smoothing or ramp control*, a function to help reduce the adverse impacts of a very fast change in renewable generation level or output; and 3) *Time-shifting*, to match typically off-peak renewable energy supply with on-peak demand.

The integration of renewable resources will be helped by the ancillary services market. The intermittency of renewable resources could be addressed in the markets or outside of them. Obligations to firm wind capacity—that is to maintain the power output at a committed level for a reasonable time—vary by region. For the most part, the obligation lies with the ISO/RTO. However, there has been movement toward requiring generators of intermittent or variable energy resources to firm their power to minimum requirements before placing their power on the grid. The management of localized voltage issues could also be addressed by energy storage outside of market-based services.

Additional distributed grid storage applications besides CES are under development. For example, thermal storage currently constitutes a large portion of the storage market today. Here, storage can be used to help shift cooling or heating loads to off-peak hours. More recently, thermal storage associated with water heaters has demonstrated the ability to participate in the ancillary services markets. In addition, microgrid demonstrations are underway that integrate storage into the portfolio of onsite resources, such as distributed generation or demand response capability. Furthermore, storage can play a role in assisting with integrating intermittent renewables on a customer site, and with providing temporary back-up power services.

3. COPPER INTENSITY

Based on market assessments and copper intensities, grid energy storage could result in a sizeable demand for copper [1]. Between 900 and 3,000 tons of copper could be used in grid energy storage in the U.S.

The copper content of grid energy storage installations can also be assessed on a per megawatt basis. Copper intensity ranges from zero to more than four tons per megawatt (MW), depending the electrical equipment type, the energy storage type and the installation configuration.

On a per megawatt basis, CES installations have the largest copper intensity, with a mid-range estimate of more than four tons per megawatt. Other distributed storage could offer high copper intensity but the majority of these installations, such as thermal energy storage, offer the lowest copper intensity, e.g., 0.04 tons per megawatt. Applications for renewable energy integration, ancillary services, and transmission services can range from 0.3 to 3 tons per megawatt.

Copper intensities vary significantly by installation and storage technology. With many storage applications in the demonstration phase, energy storage installations have yet to conform to standard configurations. Distributed applications, however, generally have higher copper intensities because they use more lower-voltage equipment, which typically has higher copper intensity. Lower voltage components are more likely to use copper due its higher conductivity and lower maintenance requirements.

At the unit level, energy storage devices range from zero to nearly 0.3 tons of copper per megawatt. Copper can play a role in the fundamental design of storage units by contributing toward internal connections and current collectors in battery technologies or motors for pumped storage or CAES devices.

Lithium-ion, flow, and sodium batteries as well as flywheels, CAES, and pumped hydropower are strong users of copper at the unit level, ranging from over 0.10 to nearly 0.3 tons per MW.

Thermal storage, lead-acid batteries, and super capacitors exhibit the lowest copper intensities, ranging from 0 to 0.03 tons per MW.

With many storage applications in the demonstration phase, energy storage installations have yet to conform to standard configurations. Energy storage installations come in a wide array of sizes and configurations and few best practices have evolved with regard to defining storage configuration. Nonetheless, common pieces of equipment will likely be needed to interconnect energy storage to the electric grid. Such equipment includes transformers; interrupting devices, such as breakers and switches; protection and communication systems; monitoring and control systems; and inter- and intra-system wiring.

Estimates of the magnitude of copper demand associated with installed applications of energy storage are based on representative configurations. Various types of equipment can be used in a variety of applications, ranging from low-voltage to high-voltage installations, and best practices are yet to develop; this range of electrical equipment associated with storage installations is accounted for by using a range of copper intensities associated with these applications.

The choice of electrical equipment, which translates into a range of copper intensities, depends on size of the equipment required in the application as well as market offerings. Reasonable ranges for the devices are used to estimate impacts on total tonnage.

The CDA-DNV GL report is based on a generic configuration that is representative of those used to estimate the copper intensity of storage installations [1]. Storage device intensities were used to estimate unit intensities. The copper content of the associated electrical equipment was estimated based on sample configurations either planned or already in the field. The copper content of the electrical equipment was estimated based on assumptions about equipment sizes and types.

The following values represent the ranges in quantity and unit size, respectively, per installation.

- Power transformers: 1 to 11; 25 kW to 360 MW
- Breakers—1 to 20; 480V to 138 kV
- Generators—2 to 200; 100 kW to 300 MW
- Inverters—1 to 48; 5 kW to 3.5 MW
- Cooling—small window units to large rooftop systems
- Grounding—several feet to miles; #4 Cu to 4/0 Cu

4. CUMULATIVE COPPER USAGE

The demand for copper comes from not only the copper content of the energy storage units themselves but also from the electrical equipment needed to operate the energy storage with the grid. The largest near-term demand for copper is in renewable energy integration and ancillary services.

Energy storage in renewable energy integration applications is associated with strong demand for copper. Cumulative associated copper demand could range from 650 to almost 2,200 tons, depending on financial incentives. Associated incremental demand could range from 300 to more than 1,800 tons.

Energy storage for ancillary services is also associated with a strong demand for copper. The copper intensities are relatively high and so are expectations for near-term growth. Cumulative demand could range from 630 tons to almost 840 tons, depending on financial incentives. Associated incremental demand ranges from over 520 tons to over 720 tons.

Meanwhile, CES is also poised for strong growth. Although near term demand is limited, this area could have strong growth for the mid-term to long-term. Estimates range from 30 to almost 370 tons, depending on financial incentives. Associated incremental copper demand ranges from over 20 tons to over 360 tons.

Although copper intensities for transmission-related storage applications are high, these markets are limited in the near term. Estimates for cumulative copper demand are 85 tons to more than 250 tons, depending on financial incentives. The associated incremental copper demand ranges from 5 to more than 170 tons.

The market for distributed thermal storage is large but copper intensity is relatively limited. Other types of distributed energy storage have higher copper intensities, but limited market penetration. Estimates for the cumulative associated copper demand range from 100 to 160 tons, depending on financial incentives. The associated incremental copper demand ranges from over 50 tons to over 100 tons.

5. MARKET FORECAST

The demand for energy storage is strong and robust but the industry needs to continue with initiatives to reduce costs and increase experience for growth to meet expectations. The CDA-DNV GL estimated that the U.S. grid storage market could grow to between two to four gigawatts (GW) by 2017, depending on the existence of financial incentives [1]. The DOE reports 991 MW of energy storage for 314 projects (not including pumped hydropower) in the U.S. alone as of April 2015 [4].

Many new technologies are under development and some are ready for commercialization. Mature energy storage technologies currently constitute the majority of the energy storage market today. These include thermal energy storage, pumped hydropower, and CAES. In the near term, battery technologies and thermal storage are expected to have the strongest growth areas.

Second generation technologies are emerging and research is continuing to be fruitful. Venture capital investment is booming both inside and outside of the U.S.

The ability to scale quickly is seen as a challenge, as is the ability to bring down costs. Financial incentives could have a large impact on market size by defraying initial investment costs and helping to grow the market.

The U.S. markets around grid-storage applications are still evolving. Policy developments are continuing to shape the development of markets around grid applications, and demonstrations are continuing to define grid application success and inform technology value propositions.

Markets around some of the grid storage applications are expanding now, such as ancillary services, and markets for other applications that are developing now, such as peaker plant applications, will likely come to fruition after five years.

In the near future, costs are expected to come down (via improved system integration, increased production, and enhanced distribution capability), investments are expected to continue, and areas currently in the demonstration phase will likely start to commercialize.

5. CONCLUSION

Because of its potential role in supporting the integration of renewable energy, energy storage may also help bolster the copper demand associated with renewable generation.

Energy storage is one of many tools available to help address renewable intermittency. Energy storage can also assist in the integration of renewable energy by helping to address transmission constraints.

The estimated copper intensities of typical wind farms and typical centralized solar plants, according to prior CDA studies, are three to six tons per MW and two to five tons per MW, respectively.

Commissioned by the Copper Development Association Inc. (CDA), the 2012 CDA-DNV GL research report entitled "Market Evaluation for Energy Storage in the United States" evaluates the near-term market for grid energy storage in the United States (U.S.) and the copper content associated with this market. CDA is the market development, engineering, and information services arm of the copper industry, chartered to enhance and expand markets for copper and its alloys in North America. It is a member of the Copper Alliance.

While it is difficult to accurately forecast the growth in the energy storage market, let alone the copper useage in that market, the CDA-DNV GL study from 2012 shows that a robust growth in the energy storage market could result in additional demand for copper amounting to several thousand tons in the near future and perhaps much more in the long term, especially if energy storage leads to wider use of alternative energies such as wind and solar.

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