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Importance of Energy Storage in Smart Grid

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Abstract: *The quality of life today is dependent upon access to a bountiful supply of cheap energy. For a sustainable future, the energy should be derived from non-fossil sources; ideally, it should also be reliable and safe, flexible in use, affordable, and limitless i.e. use of renewable sources. These renewable sources can be located anywhere on the grid, close to the load centres they serve, dispersed across the network or even in remote locations far offshore or in deserts, so such changes in traditional grid from centralized to distributed generation calls for smart grid. In the current situation with the unprecedented deployment of clean technologies for electricity generation, it is natural to expect that storage will play an important role in electric grid. This paper focused on the need and the application of energy storage in smart grid.*

1. INTRODUCTION

Energy storage is not a new concept; it has been a fundamental component of electricity generation, transmission and distribution systems from well over a century. Traditionally, energy storage needs have been met by the physical storage of fuel for fossil-fuelled power plants, by keeping some capacity in reserve and through large scale pumped hydro storage plants. By moving towards 'fuel free' power, mainly in the form of wind and solar photovoltaic (PV); dramatically change in power landscape is observed. This shifting towards the renewable sources is beneficial for the environment and sustainability. However, reliability and availability is a bigger challenge ever before. Since there is no fuel to store, the grid must have to store electrical energy efficiently after its generation. Wind and solar power plants, generates intermittent power and with a highly fluctuating output. Furthermore, unlike a traditional centralized generation plant, these renewable sources can be located anywhere on the grid, perhaps close to the load centres they serve, dispersed across the network or even in remote locations far offshore or in deserts. Such fundamental changes in the design and controllability of the grid call for smart, efficient power transmission and distribution networks. Thus the integration of renewable with grid calls for energy storage at appropriate times and locations to balance both 'ebb and flow' between generation and consumption and also to maintain grid stability. That's why energy storage is becoming a key component of smart grids.

2. SMART GRID : WHAT IT IS

The Smart Grid has no universally accepted definition, but in general it refers to modernizing the electricity grid. It comprises everything related to the electrical system between any point of electricity production and any point of consumption. Through the addition of Smart Grid technologies the grid becomes more flexible and interactive and can provide real time feedback. For instance, in a Smart Grid, information regarding the price of electricity and the situation of the power system can be exchanged between electricity production and consumption to realize a more efficient and reliable power supply. EES is one of the key elements in developing a Smart Grid. A smart grid delivers electricity from suppliers to consumers using digital technology with two-way communications by controlling appliances, increasing reliability & transparency, energy saving, cost reduction.

3. NEED OF ENERGY STORAGE

Energy Storage can supply more flexibility and balancing to the grid, providing a back-up to intermittent renewable energy. Locally, it can improve the management of distribution networks, reducing costs and improving efficiency. In this way, it can ease the market introduction of renewable, accelerate the decarbonisation of the electricity grid, improve the security and efficiency of electricity transmission and distribution, stabilise market prices for electricity, while also ensuring a higher security of energy supply. [3] A smart grid delivers electricity from suppliers to consumers using digital technology with two-way communications to control appliances, save energy, reduce cost, increase reliability and transparency It overlays the electricity distribution grid with an information and net metering system. Turning the entire energy conversion chain into a smart infrastructure Decentralized energy management system, Power transmission, Condition monitoring/ asset management, Smart substation automation [4]

The typical grid energy storage applications are summarized as:

Services and Functions of Energy Storage for supply system:

Electric Supply Reserve Capacity: Prudent operation of an electric grid includes use of electric supply reserve capacity (reserve capacity) that can be called upon when some portion of the normal electric supply resources become unavailable unexpectedly. In the electric utility realm, this reserve capacity is classified as an ancillary service

Spinning reserve: Generation capacity that is online but unloaded and that can respond within 10 minutes to compensate for generation or transmission outages. To provide effective spinning reserve, the energy storage system is maintained at a level of charge ready to respond to a generation or transmission outage. Depending on the application, the system can respond within milliseconds or minutes and supply power to maintain network continuity while the back-up generator is started and brought on line. This enables generators to work at optimum power output, without the need to keep idle capacity for spinning reserves. It can also eliminate the need to have back-up generators running idle.

Supplemental Reserve – Generation capacity that may be offline or that comprises a block of curtailable and/or interruptible loads, and that can be available within 10 minutes.

Backup Supply – Generation that can pick up load within one hour. Its role is, essentially, a backup for spinning and supplemental reserves. Backup supply may also be used as backup for commercial energy sales. Importantly for storage, *generation* resources used as reserve capacity must be online and operational (*i.e.,* at part load). Unlike generation, in almost all circumstances, *storage* used for reserve capacity does not discharge at all – it just has to be ready and available to discharge *if need.*

Electric Energy time shift: Electric energy time-shift (time-shift) involves purchasing inexpensive electric energy, available during periods when price is low, to charge the storage plant so that the stored energy can be used or sold at a later time when the price is high.

Services and Functions of Energy Storage for ancillary services:

Area Regulation: Area regulation (regulation) is one of the ancillary services for which storage may be especially well-suited. Regulation involves managing "interchange flows with other control areas to match closely the scheduled interchange flows" and moment to moment variations in demand within the control area.

Voltage Support An important technical challenge for electric grid system operators is to maintain necessary voltage levels with the required stability. In most cases, meeting that challenge requires management of a phenomenon called 'reactance'. Reactance occurs because equipment that generates, transmits, or uses electricity often has or exhibits characteristics like those of inductors and capacitors in an electric circuit. To manage reactance at the grid system level, grid system operators rely on an ancillary service called 'voltage support'. The purpose of voltage support is to offset reactive effects so that grid system voltage can be restored or maintained.

Transmission Support Energy storage used for transmission support improves T&D system performance by compensating for electrical anomalies and disturbances such as voltage sag, unstable voltage, and sub-synchronous resonance. The result is a more stable system with improved performance (throughput).

Transmission Congestion Relief In many areas, transmission capacity additions are not keeping pace with the growth in peak electric demand. Consequently, transmission systems are becoming congested during periods of peak demand, driving the need and cost for more transmission capacity and increased transmission access charges. Additionally, transmission congestion may lead to increased use of congestion charges or locational marginal pricing (LMP) for electric energy. Storage could be used to avoid congestion-related costs and charges, especially if the charges become onerous due to significant transmission system congestion. In this application, storage systems would be installed at locations that are electrically downstream from the congested portion of the transmission system. Energy would be stored when there is no transmission congestion, and it would be discharged (during peak demand periods) to reduce transmission capacity requirements.

Substation On-site Power They provide power to switching components and to substation communication and control equipment when the grid is not energized.

Services and Functions of Energy Storage for Grid Operators:

Frequency regulation The energy storage system is charged or discharged in response to an increase or decrease, respectively, of grid frequency. This approach to frequency regulation is a particularly attractive option due to its rapid response time and emission-free operation.

Electric Service Reliability The electric service reliability application entails using energy storage to provide highly reliable electric service. In the event of a complete power outage lasting more than a few seconds, the storage system provides enough energy to ride through outages of extended duration; to complete an orderly shutdown of processes; and/or to transfer to on-site generation resources.

Power quality In power quality applications, an energy storage system helps protect downstream loads against short-duration events that affect the quality of power delivered. Energy storage used for transmission support to maintain power quality improves T&D system performance by compensating for electrical anomalies and disturbances such as voltage sag, unstable voltage and sub-synchronous resonance. The electric service power quality application involves using energy storage to protect on-site loads downstream (from storage) against short-duration events that affect the quality of power delivered to the load. Some manifestations of poor power quality include the following:

- Variations in voltage magnitude (*e.g.*, short-term spikes or dips, longer term surges, or sags).
- Variations in the primary 60-Hz frequency at which power is delivered.
- Low power factor (voltage and current excessively out of phase with each other).
- Harmonics (*i.e.*, the presence of currents or voltages at frequencies other than the primary frequency).
- Interruptions in service, of any duration, ranging from a fraction of a second to several or even many minutes.

Load leveling Load leveling usually involves storing power during periods of light loading on the system and delivering it during periods of high demand. During these periods of high demand the energy storage system supplies power, reducing the load on less economical peak-generating facilities. This allows for the postponement of investments in grid upgrades or in new generating capacity.

Voltage support An energy storage system can help to maintain the grid voltage by injecting or absorbing both active and reactive power.

Voltage control ES can help to maintain the voltage profile within a defined range, with the aim to guarantee standard of supply. ES achieves this by storing energy when the voltage is high, and feeding in when voltage is low.

Peak shaving Peak shaving is similar to load leveling, but may be for the purpose of reducing peak demand rather than for economy of operation. The goal is to avoid the installation of capacity to supply the peaks of a highly variable load. Peak shaving installations are often owned by the electricity consumer, rather than by the utility. Benefits:

—Commercial and industrial customers save on their electricity bills by reducing peak demand

—Utilities reduce the operational cost of generating power during peak periods (reducing the need for peaking units)

— Investment in infrastructure is delayed due to the flatter loads with smaller peaks.

Integration of renewable energy into the grid ES can provide control power to limit fluctuations offeed-in electric power into the low voltage grid, and potentially also for large photovoltaic farms in the middle voltage grid. It can also shave off renewable peak generation in times of high production and low consumption, minimising grid congestion and/or RES curtailment. This function also provides voltage support on distribution feeder lines. This may allow for the deferral of any necessary grid upgrade or extension.

Functions of ES in End-user applications

Time-shift for self-consumption ES can provide power during RES non-generation hours, allowing the household or building to increase independency from the electrical-grid. In the mid-term, this could reduce the overall electricity price by smart-metering, where stored energy is discharged during peak load hours when electricity prices are high. The primary renewable energy source will be Photovoltaic.

Time-shift for feed-in ES can provide power when renewable energy source supply is below demand or in non-generating hours. It can create economic value through electrical energy trading to (for example) the local utility industry via “storing-selling consumption”. The primary renewable energy source will be PV.

Smoothing of RES feed-in ES has the capacity to smooth RES feed-in by providing, absorbing and delivering power to limit fluctuations of feed-in electricity in the low voltage grid. This will improve overall grid conditions, with higher shares of renewable energy employed. Appropriate energy sources are photovoltaic and wind energy.

Uninterruptible Power Supply (UPS) ES allows for increased power safety in areas with weaker low voltage grids. It has the capacity to provide backup power through the entirety of a power outage period. The number of cycles is dependent on overall grid stability.

Demand Charge Management

Energy storage could be used by electricity end users (*i.e.*, utility customers) to reduce the overall costs for electric service by reducing demand charges, by reducing power draw during specified periods, normally the utility’s peak demand periods.

Time-of-use Energy Cost Management Time-of-use (TOU) energy cost management involves storage used by energy end users (utility customers) to reduce their overall costs for electricity. Customers charge the storage during off peak time periods when the electric energy price is low, then discharge the energy during times when on-peak TOU energy prices apply. This application is similar to electric energy time-shift, although electric energy prices are based on the customer’s *retail* tariff, whereas at any given time the price for electric energy time-shift is the prevailing *wholesale* price.

Electric Service Reliability The electric service reliability application entails using energy storage to provide highly reliable electric service. In the event of a complete power outage lasting more than a few seconds, the storage system provides enough energy to ride through outages of extended duration; to complete an orderly shutdown of processes; and/or to transfer to on-site generation resources.

4. CONCLUSION

Applications for which energy storage can be used in smart grid application are reviewed in this paper. Increasing complexity of power grids, growing demand, and requirement for greater reliability, security and efficiency as well as environmental and energy sustainability concerns continue to highlight the need for a quantum leap in harnessing communication and information technologies. This leap toward a “smarter” grid is widely referred to as “smart grid. The quality of renewable energy sources such as solar and wind power largely depends on the weather. The efficiency of the power supplied by these renewable energy sources can be maximized when paired with an energy storage system.

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