GRAVITATIONAL POTENTIAL ENERGY STORAGE

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INTRODUCTION

While technological innovation in energy storage has taken off, the current infrastructure is limited in the amount of energy that can be stockpiled from intermittent sources such as solar and wind power. Renewable energy is becoming affordable, but the intermittent nature of production and reliance on the right solar and wind conditions has held back renewables in the quest to replace fossil fuels.

Taking its inspiration from hydropower, Switzerland-based start-up company Energy Vault has developed a new kind of storage method. The system essentially harnesses the power of the Earth's gravitational pull, using concrete bricks that are raised and lowered automatically by a crane onto a tower structure.

Figure 1. Wind turbines electricity stored then retrieved from a gravitational potential energy storage tower.

HISTORY

The storage technology incorporates basic principles of physics that have been used in the production of pumped hydropower plants for years. In pumped hydro systems, water flows down from an upper reservoir to a lower reservoir, passing through and rotating a generator or turbine. Water is then pumped back up from the lower to the upper reservoir, at some electrical cost, which again rotates the turbines and the system is repeated, thus generating and containing electricity.

In a similar vein, the Energy Vault Company has developed a six-arm crane to lift 5,000 concrete blocks, weighing 35 tonnes in total, up and down a 33-stories building, which store gravitational potential energy when they are raised, and release it as they are lowered.

In each gravity-based energy storage, a certain mass is moved from a lower point to an upper point – with the use of a pump, if water for example which represents 'charging' the storage, and from a higher to a lower point which creates a discharge of energy.

Increasing the height of a large mass implies storing electricity in the form of potential energy. On the other hand, in order to release the power, kinetic energy is created from the downward movement of the mass, thereby creating the electricity.

The innovation comes in its application of cloud-based automation software, which operates the six-arm crane mechanically, and manages the distribution of power to either store energy from solar and wind assets, or discharge it to the grid when needed.

COMPARISON TO OTHER STORAGE TECHNOLOGIES

Existing energy storage systems are currently very costly. Tesla's 100 MW/129 MWh battery technology installed in Australia cost the company around $66m to produce. Hydro-electric power storage plants that require man-made dams to produce energy can cost billions of dollars to construct, although they can store significantly more energy than 100 MW. The largest hydro storage plant in the world is the Bath County Pumped Storage Station in Virginia, USA, which cost $1.6 bn in 1985 and has a storage capacity of around 24,000 MWh.

In contrast, Energy Vault's gravity storage units cost around $7m-$8m to build, and have a lower levelized storage cost of electricity, which measures on a per kWh basis the economic break-even price to charge and discharge electricity throughout the year. It is considered by some to create a more accurate measurement of energy costs.

The methodology is lower-cost than pumped hydro plants both on an initial capital expenditure basis and levelized cost of storage (LCOS) basis. The LCOS takes into account not only the initial capital expenditure but also the operating, maintenance and replacement cost. Pumped hydro has a LCOS of $0.17/kWh; the Energy Vault's solution is below $0.05/kWh.

The system is around 50 percent cheaper than battery storage technology, in particular lithium-ion batteries, which can have an LCOS of around $0.25/kWh-$0.35/kWh. One of the reasons for this is the cost of battery materials, which is much higher than the cost of concrete provided to Energy Vault by Mexican company Cemex.

Another advantage is a short ramp rate. A ramp rate is the time taken for a plant's power output to ramp up or down. The ramp rate for Energy Vault's gravity storage solution is as little as one millisecond, and the storage system can go from zero to 100% power in no more than 2.9 seconds. The system has round-trip power efficiency, i.e. zero to full power to zero, of 90% efficiency, meaning only 10% energy loss.

Because pumped hydro requires you to utilize a motor-driven pump to move the water to a higher location, there is a significant loss of energy storage capacity of approximately 30%. Pumped hydro plants have a round-trip efficiency of around 70%, whereas the Energy Vault system has a round-trip efficiency of between 88%-92%, which allows for a greater energy storage capacity and thus fundamentally better economics.

FUTURE PROSPECTS

Indian energy provider Tata Power was one of the first firms to show interest in bringing the gravity storage system into commercial operation. In November 2018, Energy Vault made a deal with Tata Power to deploy a 35 MWh system this year. The project, which is small-scale compared to the technology's potential, will have a peak power output of 4 MW.

Ultimately, the success of gravity storage solutions will depend on their ability to be cost-competitive with other forms of storage in the long term. There are potential advantages in high round-trip efficiencies, negligible self-discharge and an ability to participate in multiple markets. Novel gravity-based technologies show potential to be technically valuable to future energy systems if they can provide certainty to investors of their long-term market.