POWERWALL AND POWERPACK TESLA BATTERIES

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"It is waiting that helps you as an investor, and a lot of people just cannot stand to wait."
Charles Munger

INTRODUCTION

It is interesting to realize that the existing North American electric grid, considered as the most complex machine ever invented and operated by humans, can work as well as it does with no substantial energy storage provisions. There is no standard way to store electricity on the present electric grid: if there is a surge in demand, the power companies have to fire up their extra spinning-reserve direct-cycle or combined-cycle gas turbine power plants. It is an entire market for energy transactions without inventory nor buffer. Electricity is delivered as a service instantaneously just in time, not as a commodity; suggesting the existence of an enormous amount of unnecessary waste.

As a consequence, a market is developing where an Electric Vehicle (EV) company like Tesla considers selling cheaply manufactured batteries to consumers, businesses, and homeowners to store that wasted grid-available energy at times of low demand for use at times of high demand or in times of emergencies. People can even generate their own energy from intermittent sources such as wind and solar energy, and with a modest backup system, reduce their dependency on the existing electrical utilities model.

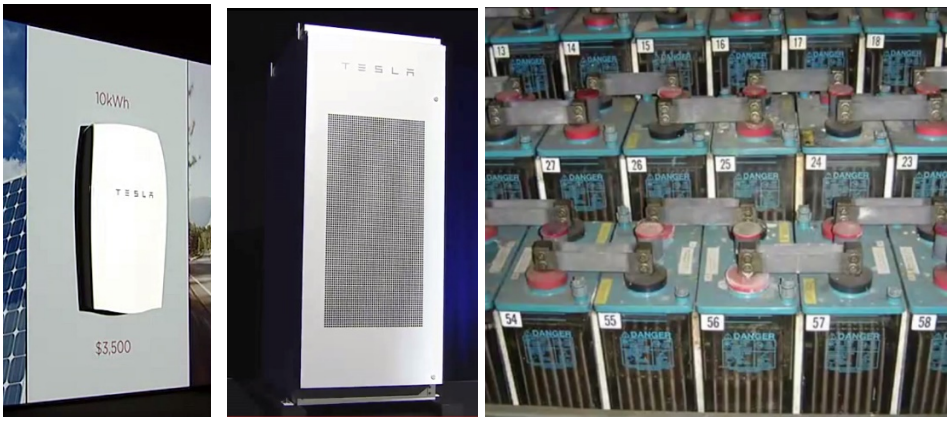

Figure 1. A 10 kW.hr capacity Tesla "Powerwall" battery costing $3,500, and a 100 kW.hr Tesla "Powerpack" as replacements of existing "expensive, unreliable, poor integration, poor lifetime, low efficiency, not scalable, unattractive," and dangerous existing electrical storage batteries. Source: Tesla Power.

GIGAFACTORY1 BATTERY FACTORY

Tesla chose an industrial park outside Reno, Nevada, to build its battery "Gigafactory1." This takes closer to mass producing an electric car that costs around $35,000 and can go 200 miles on a single charge by 2017. The new factory would give Tesla a possible advantage over its competitors, mainly General Motors and Nissan Motor, which also are racing to build a relatively affordable electric car with a range that lets people take most daily trips without recharging. Tesla has shown that hundreds of miles of range is possible, but the sales volume and technology are not available yet to get the cost below the $70,000 base price of the Model S luxury sedan Tesla sells for.

The gigafactory, with a projected 6,500 jobs and 10 million square feet, equivalent to about 174 football fields, would bring the cost of batteries down by producing them on a large scale. Tesla wants the factory running by 2017, when it has promised the new, relatively affordable Model 3 vehicle, and producing batteries for about 500,000 vehicles annually by 2020.

Tesla will pay about half of the Nevada factory's cost. The other major investor is Japan's Panasonic Corporation, which will manufacture the lithium-ion battery cells and invest in equipment. Aside from low tax rates and business-friendly workplace laws, Nevada offered plenty of sun and wind to generate "green" power, and relative proximity to the company's car manufacturing plant in the San Francisco Bay Area.

The industrial park 20 kms east of Reno also is near a deposit of lithium, an essential element to produce the battery cells.

Figure 2. Gigafactory1 solar-powered battery manufacturing facility in Reno, Nevada, USA. Source: Tesla Power.

JUSTIFICATION

One third of the fossil fuels consumed in the USA are used in the transportation sector and another one third goes into electricity production. The USA electric power sector alone produces over 2,000 million metric tons of CO_2 per year which is equivalent to burning 225 billion gallons of gasoline per year. The Environmental Protection Agency (EPA) suggests that it would require 1.6 billion acres of USA forests to negate the environmental damage.

Relying on renewable energy sources for power consumption, the top 50 percent of the dirtiest power generation resources could be retired early, resulting in a cleaner, smaller, and more resilient energy grid. Electrical energy storage in batteries, enables homes, businesses, and utilities to store sustainable and renewable energy to manage power demand, provide backup power and increase the electrical grid resilience.

POWERWALL SMALL SCALE STORAGE BATTERY

The Powerwall battery is a rechargeable Li-ion battery designed to store Photo Voltaic (PV) solar energy at a residential level for load shifting, backup power and self-consumption of solar power generation. It consists of a Li-ion battery pack, a liquid thermal control system and software that receives dispatch commands from a solar inverter. The unit mounts seamlessly on a wall and is integrated with the local grid to harness excess power and give customers the flexibility to draw energy from their own reserve.

Other applications include:

1. Load shifting: The battery can provide financial savings to its owner by charging during low rate periods when demand for electricity is lower and discharging during more expensive rate periods when electricity demand is higher
2. Increasing self-consumption of solar power generation: The battery can store surplus solar energy not used at the time it is generated and use that energy later when the sun is not shining.
3. Back-up power: Assures power in the event of an outage.

It is available in 10 kW.hr, optimized for backup applications or 7 kW.hr optimized for daily use applications. Both can be connected with solar or grid sources and both can provide backup power. The 10kW.hr Powerwall is optimized to provide backup when the grid goes down, providing power for a home when needed. When paired with PV solar power, the 7 kW.hr Powerwall can be used in daily cycling to extend the environmental and cost benefits of stored solar energy into the night or on cloudy days when sunlight is unavailable.

Tesla's initial selling price to installers is $3,500 for the 10 kW.hr and $3,000 for the 7 kW.hr of capacity batteries. The price excludes the inverter and the installation cost.

Table 1. Powerwall technical Specifications.

Mounting	Wall–mounted, indoor or outdoor
Dimensions	H:W:D 130:86:18 cm
Inverters	In pairs
Energy storage capacity	7 or 10 kW.hr
Continuous power delivery	2 kW
Peak power	33 kW
Round-trip efficiency	>92 percent
Operational temperature range	[- 20, + 43] ^{o}C, [- 4, + 110] ^{o}F
Manufacturer warranty	10 years

The Fronius and Tesla Companies offer Powerwall in combination with the Fronius Symo Hybrid inverter for residential PV systems. For new PV installations, the Fronius inverter can be used to operate both the PV and the Powerwall. For homeowners who already have solar PV, the Fronius inverter can be added to the system as AC-coupled, or replace the existing inverter as DC-coupled. The Fronius inverter will function with most types of solar energy systems.

Another possibility is the SolarEdge PV DC-optimized inverter that can control both the PV and the storage functions.

POWERPACK BUSINESS SCALE ENERGY STORAGE

Based on the powertrain architecture and components of the Tesla electric vehicles, Tesla Energy integrates batteries, power electronics, thermal management and controls into a turn-key system. It anticipates and discharges stored power during a facility's times of highest usage, reducing the demand charge component of the energy bills.

Figure 3. Powerpack units used for refrigeration at Jackson Family wineries in Central and Northern California, USA.

The energy storage for business Powerpack battery is designed to:

1. Maximize consumption of on-site clean power,
2. Avoid peak demand charges,
3. Purchase electricity when it is cheapest,
4. Get paid by utility or intermediate service providers for participating in grid services,
5. Back up critical business operations in the event of a power outage.

The EnerNOC's energy intelligence software helps customers make the most of Tesla's energy storage systems by integrating them into an overall energy management strategy, optimizing battery usage during high price periods and enabling customers to utilize batteries for demand charge management and demand response.

ELECTRICAL UTILITIES ENERGY STORAGE

For utility scale systems, 100 kW.hr battery blocks are grouped to scale from 500 kW.hr to 10 MW.hr of storage capacity. These systems are capable of 2 hour or 4 hour of continuous net discharge power, using grid-tied bi-directional inverters. Systems support applications include peak shaving, load shifting and demand response while offering, renewable firming and a variety of grid services at utility scales. Tesla Energy for Utilities is designed to:

1. Firm up renewable generation by reconciling the intermittency of power from these sources and storing excess capacity to dispatch when it is needed,
2. Increase resource capacity by acting as an on-demand distributed power generation system, contributing to the overall generating capacity while adding resiliency to the grid,
3. Ramp Control, by acting as a buffer while the power output from a large generation source is ramping up or down, delivering power instantly to smoothly transition output to the required level,
4. Improve power quality by preventing fluctuations from propagating to downstream loads,
5. Defer costly and time-consuming infrastructure upgrades,
6. Manage peak demand by deploying power within seconds or milliseconds.

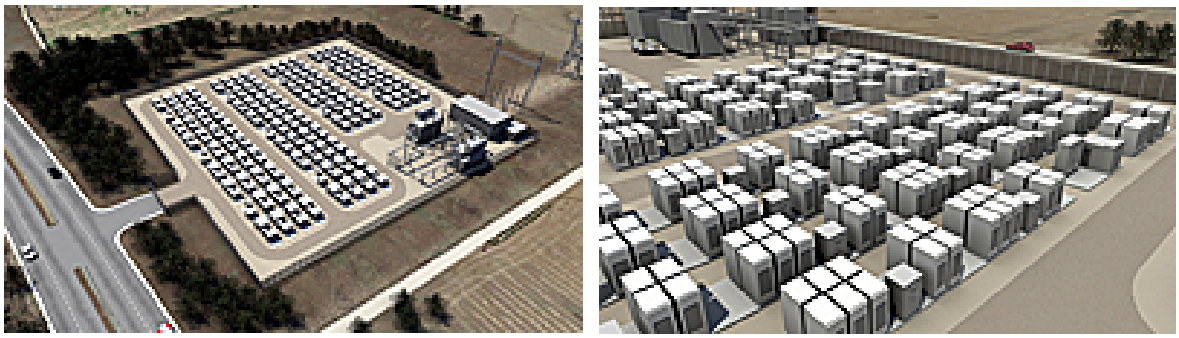

Figure 4. Utility electrical storage configurations. Source: Tesla Power.

DISCUSSION

It is inevitable that a new combined distributed and centralized electrical generation and energy conveyance system will evolve under the umbrella of the Internet of Things, IoT. The advances in battery technology will change the way we build our cities and produce and consume energy.

The electric industry is evolving, as well as the consumers' needs for electric service. The future needs a flexible, adaptive electric grid, which can only be accomplished through the use of technology like advanced meters, smart grid and electric storage.

Southern California Edison (SCE), the regulated utility subsidiary of Edison International, has developed the nation's largest battery storage system and has contracts in place for an additional 264 MWs of storage. SCE is working with Tesla on three demonstration projects that can help drive down the cost of battery storage systems for residential and business customers, as well as Electric Vehicles (EV) drivers. These demand response demonstration projects will test communication capabilities and explore rebates to customers who allow SCE to manage their

battery charging in order to increase the use of renewable energy while ensuring continued grid reliability.

REFERENCES

1. Tesla Energy, http://www.teslamotors.com/presskit/teslaenergy.