PUBLIC – FOR GENERAL RELEASE

The Tanktwo String Battery™ for Electric Cars

Architecture and introduction

TANKTWO

questions@tanktwo.com

www.tanktwo.com

TANKTWO

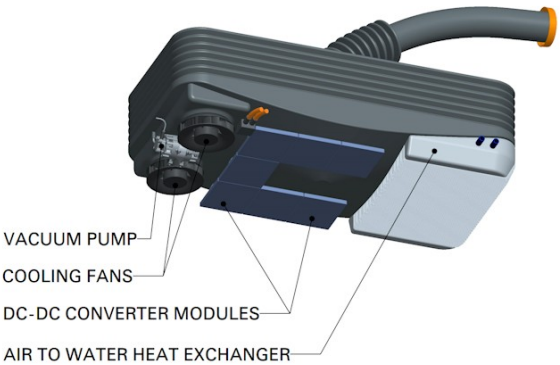
Introduction

In March 2015, Tanktwo introduced a completely new battery for Electric Vehicles and their complementary ecosystem. The system offers significant cost benefits and unprecedented recharging speeds. This highly customizable energy storage solution can use any current and future battery chemistry.

This new technology is based around the concept of the string battery, which offers many benefits that surpass the energy storage solutions currently employed by EVs. The string battery technology removes the need for over-dimensioning of EV batteries. Traditionally over-engineering has been done for several reasons, such as to meet a minimum battery lifetime requirement; or to prevent noticeable performance degradation caused by individually failing cells. With the string battery, a malfunctioning or depleted cell can be isolated in such way that it does not affect, in practice, the overall performance of the battery. In addition, individual cells are easily isolated and inexpensively replaced in cell stations. Easy replacement allows for higher individual cell failure rates, and therefore cells can be exposed to a greater amount of stress, for example by utilizing a wider charge/discharge window. Under most current

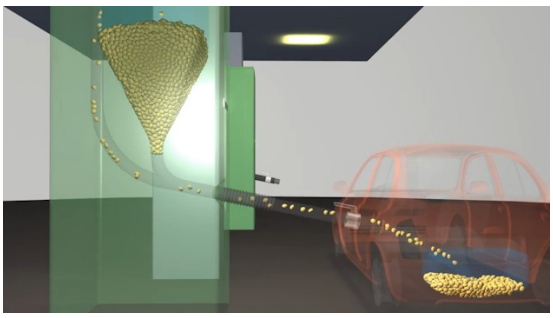
STRING BATTERY ™

A string battery is a type of rechargeable battery that consists of many individual electrochemical cells placed inside a battery enclosure in random order. The individual cells and the enclosure form a dense, random electrical connection network that can be organized to create an optimal cell connection circuit which typically consists of many series connected cell strings.



CELL STATION

Cell stations primarily perform cell swapping and charging of string cells. Compared to a more traditional charging station, a cell station has containers for storing string cells, in which the actual charging takes place. Instead of EV charging outlets, a user will find a hose system for moving string cells from a storage container to a string battery inside an EV. Peak energy consumption of a cell station is drastically lower than a traditional high-speed charging station, as the string cells in the cell station do not need to be charged while the user is present. They can therefore also act as an energy storage buffer.



Tanktwo
48 Wall St., 5th floor, New York, NY 10005, USA +1-212-321-0630
Teknobulevardi 3, 01530 Vantaa, Finland +358-40-5180025

systems, identifying and replacing a broken cell can be very difficult or impossible.

Cost savings

The user has the freedom to carry only the amount of cells needed to satisfy their typical driving patterns. Traditional EV batteries cost between $5,000 and $50,000, and the provided range can be anywhere between, say, 50km and 500km. With the String Battery system there is no need to fill the enclosure to its maximum capacity. When needed the user can obtain more string cells from a cell station to increase range or performance. The weight of a full-size EV battery often exceeds half a metric ton. Although large EV batteries can offer up to 500km of range, users generally use just a portion of this range for day to day use. Reducing the weight of the battery creates significant savings in both initial investment and daily energy consumption.

There are also several benefits for manufacturers of EVs and EV batteries. The easy replacement of string cells allows for wider manufacturing tolerances, for example opening up the possibility to use cheaper battery cells, as the lifetime of a single string cell does not *have to be guaranteed* for years. Hence EV batteries are easier to design, less expensive to produce and they make EVs more economically viable. As technology progresses and more advanced string cells are put into circulation, the pool of string cells in use will gradually increase the performance and benefit from new development.

Any existing EV charging station can be easily and inexpensively converted into a string battery cell station. As the string cells are charged over time in large containers, the load on the electrical grid can even be reduced to zero during times of peak demand. Traditional fast charging stations are a nightmare for heavily loaded grid nodes, as moments of peak load tend to coincide with times when people want to fast-charge their cars. With the Tanktwo system, new cell stations can be built even in areas that would not traditionally support fast charging stations.

CELL SWAP

Cell swapping is the method of replacing string cells placed inside the string battery – which is technically also a battery enclosure. To enable cost efficient cell swapping, the individual cells have to support some type of automatic removal, installation and conveying methods. In addition to replenishing energy, cell swapping is commonly used to replace certain cells with some that can hold more energy, or have better performance or qualities otherwise.

Fast charging

Typically, EV users charge their vehicles overnight. Slow charging maximizes the battery longevity and remains the general way to recharge EV batteries. String batteries will most commonly be recharged overnight as well. However, where the string cell technology differs is in the possibility it provides to replenish the string battery charge within a few minutes. This is done without the problems typically associated with fast charging, such as increased battery wear and high peak loads on the electricity grid. String cell battery technology allows the depleted cells to be swapped for fully charged cells in a process called cell swapping. Cell swapping differs from traditional battery pack swapping technologies in that only the cells are swapped. Swapping

Tanktwo
48 Wall St., 5th floor, New York, NY 10005, USA +1-212-321-0630
Teknobulevardi 3, 01530 Vantaa, Finland +358-40-5180025

cells in a string battery typically takes less time than traditional petrol cars take to fill up.

Adaptability

The modular, independent construction means that different versions of string cells can be used within the same string battery, making the string battery serviceable, future-proof and upgradable. String cells can support any current or future battery chemistry and will benefit from other improvements in the field of material science, embedded computing and electronics.

An additional advantage of the string cell battery is the flexibility allowed in shaping the battery enclosure. Compared to batteries with a fixed architecture, the string cell battery allows EV designers to easily configure the string battery's enclosure so that it conforms to the size and shape of different vehicle platforms. These different string batteries can still use the same string cells, if certain design rules are followed. Following these rules, manufacturers can also design new types of string cells, that can then be used in the public ecosystem. Tanktwo defines a certain set of design rules, which allow any manufacturer to design string cells that are compatible with the public ecosystem. Tanktwo also provides design and simulation tools to aid in the development process.

Tanktwo String Cell ™

The string battery solution is based on a distributed and modular design that consists of automatically self-organizing cells, which are called string cells. The string cell is a modular and independent unit inside the string battery. A single string cell consists of a plastic enclosure, an electromechanical cell, a number of contacts, and internal processing capabilities. Through the conductive material on the surface of the enclosure, string cells form contacts with one another. The terminals of the internal electrochemical cell can be connected to any of the contacts, controlled by the internal processing unit.

Individual string cells are identified and analyzed separately. The internal processing unit monitors and stores the temperature, state-of-charge, number of charge cycles and other values to determine its health. This information can be used for further analysis in later stages and to ensure safe operation of the battery. If, for example, the internal temperature of a string cell would rise over any predetermined safety limit, the string cell will limit the amount of power it supplies or absorbs. Even if the individual string cell would disconnect the internal cell altogether, it would not significantly affect the operation of the rest of the battery.

Tanktwo String Battery

A string battery consists of an enclosure, a control unit and a power electronics unit. The

Tanktwo
48 Wall St., 5th floor, New York, NY 10005, USA +1-212-321-0630
Teknobulevardi 3, 01530 Vantaa, Finland +358-40-5180025

enclosure holds string cells in random order and orientation. Internal pressure can be applied to prevent the string cells from moving and ensures reliable galvanic connections between string cells during operation.
To deliver power, the control unit maps the string cells and the randomly created electric network. This network data is then processed to select the most optimal combinations of cells. Periodically the routes are optimized to respond to changes in battery status.
The power electronics unit is used to combine the electrical power from multiple strings into a single power output and to transfer voltages to the required output level. To provide optimal power usage under any given conditions, the connected string cells can form a large number of combinations. This ability allows the string battery to optimize for power, range and lifetime.

String cell swapping

The Tanktwo system enables fast and economical cell swapping and a dynamic ecosystem designed to work in any type of environment, public or private. The modular and adaptive nature of the string cell makes it possible to transport string cells in containers and move them like any bulk material. For example, pneumatic conveying has proven to be an efficient way to move string cells from one container to another.
In the public Tanktwo string battery ecosystem, the cell swapping typically takes place at a Tanktwo equipped cell station. EV users drive up to the station where, upon arrival, the vehicle and the swapping system wirelessly conduct an electronic 'handshake'. Each party announces their interest in a potential transaction, after which an assessment of the options is performed. The cell station is informed about the state and residual value of the string cells inside the EV, and the user is informed of the various types the cell station has available, if any. The residual value of string cells is determined based on usage history, original value, capacity, type, and contained energy, amongst other factors. The amount of string cells can be fully altered based on the user's needs. After approval by the user and his financial ability is ensured, the user briefly waits as the station empties the string battery and refills it with the freshly charged string cells. After financial clearing and billing, the transaction is considered closed.
Individual string cells can be segregated in cell stations according to the quality, capacity or value of the string cell. This information places them in into appropriate categories, from which the user can choose to fill his or her string battery. If a cell is detected to have a malfunction or if the capacity has dropped below a minimum threshold, it is removed from circulation and fully recycled.

Battery maintenance

It is not necessary to have a network of cell stations deployed in order to actualize the benefits of the String Battery. As a matter of fact, even without a single location where cell swapping for energy replenishment reasons is done, the string battery has benefits for EVs operating under traditional, non user-swappable, battery models.
Outlets which offer maintenance and repair services can utilize simplified manual swapping systems. Here, the purpose is not to replenish the string battery with energy, but to find string cells whose energy levels have deteriorated below a certain level, or are malfunctioning

altogether.
Non-user serviceable string batteries are opened at the maintenance outlet by a technician, after which the string cells are removed with a device that is not unlike a shop-vac. This device analyzes the status and health of the removed string cells, and can return the cells that meet or exceed the minimum performance threshold back to the string battery. The maintenance technician can then choose to replace the removed under-performing cells with new ones, if the capacity or performance of the string battery is to be restored.
As string cells are intrinsically safe and only deliver power under guaranteed non-human hazardous circumstances, string batteries and string cells can be maintained by service personnel that is not trained in high voltage electronics and can be conducted without specialized high voltage tools. In addition, analysis and performance restoration of string batteries takes mere minutes.

Conclusion

The system described in this paper represents the near future of electricity storage solutions for electric vehicles and similar applications. The Tanktwo String Battery solves the current EV battery problems of high investment costs, non-serviceability and relatively slow-to-charge solutions. It also makes it easier and more cost effective to build new EV charging stations.
All things people have come to expect from regular electric vehicles remains available without exception. In addition, the String Battery enables infinite range, significantly reduced cost, and the opportunity to benefit from future technologies as time progresses.
The Tanktwo String Battery also provides opportunities for an ecosystem of cell stations. Charging String Cells can drastically help spread grid load induced by EV charging, and in many cases make grid capacity upgrades unnecessary.
Not only is the Tanktwo String Battery the fastest energy replenishment system for electrical cars, it is even faster than buying gasoline.

Tanktwo
48 Wall St., 5th floor, New York, NY 10005, USA +1-212-321-0630
Teknobulevardi 3, 01530 Vantaa, Finland +358-40-5180025