The Tanktwo String Battery™ for Electric Cars

Ecosystem Description

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Pre-reading

Before reading this document it is recommended to read the "White Paper 1: String Battery Introduction" document, which describes the concept of string battery and string cells. Figure 1 illustrates the Tanktwo information path i.e. the different technical information sources with recommended reading order.

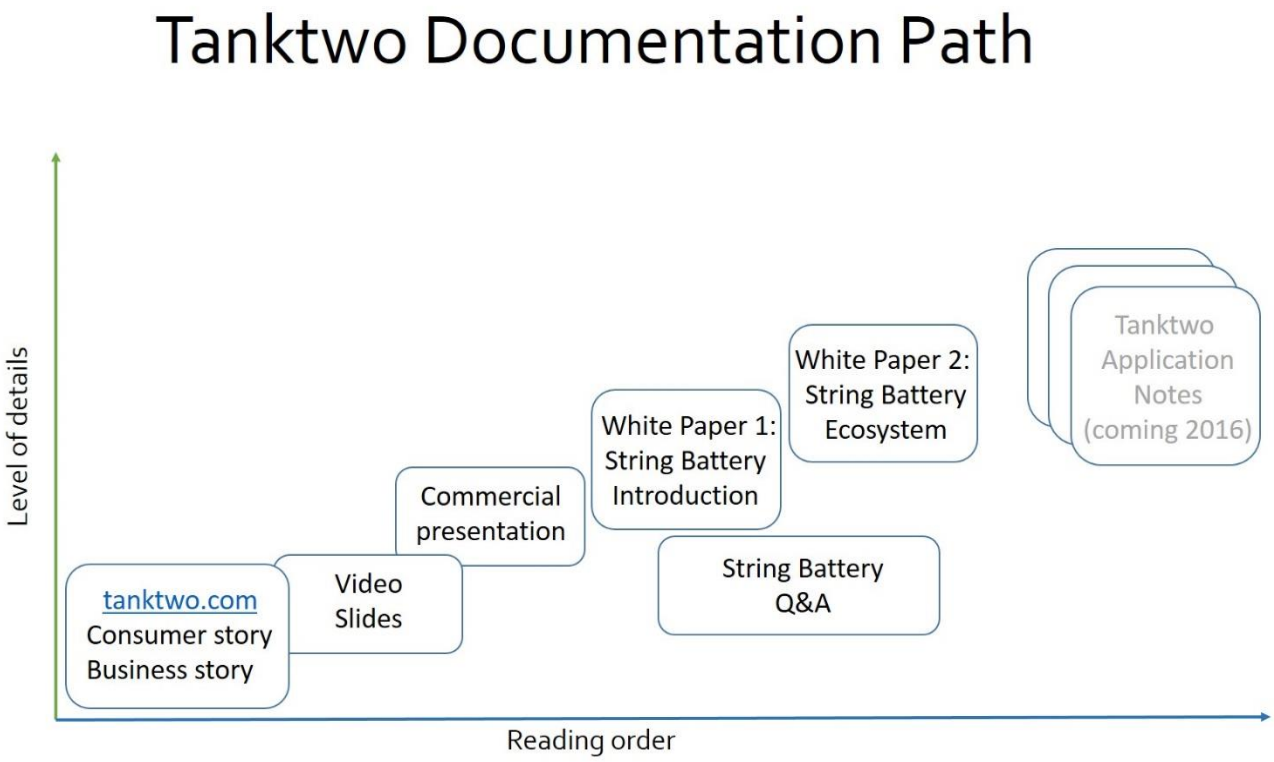

Figure 1: Tanktwo documentation path

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Introduction

In March 2015, Tanktwo introduced a completely new battery category for Electric Vehicles (EV) 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. It is based around the concept of the string battery, which offers many benefits that surpass the energy storage solutions currently employed by EVs.

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.

Tanktwo technology is suitable for a variety of purposes, ranging from small private systems to nationwide and public electric vehicle systems. In a private system the owner (e.g. a company or governmental system) has full control of all components used in the system with the added ability to tailor the system architecture according to their requirements. In a public system where users swap string cells at public cell stations, more complex architecture is needed to provide authentication and fair exchange value estimation functionality.

Swapping string cells is not the only available possibility to charge the user's string battery. Tanktwo string battery fully supports traditional plug-in battery charging from the grid or from solar panels.

Ownership
Tanktwo ecosystem supports several ownership models. String cells can be owned by organizations, leasing companies or private persons. During the string cell swap the ownership of swapped cells is updated. In private systems, ownership may stay inside the same organization between string cell swaps.

Users
A user is a person who is using the electric vehicle, powered by the string battery. Tanktwo ecosystem offers users information and the tools to make their life easier.

On a high abstraction-level the string cell based EV solution and the supporting global Tanktwo string battery ecosystem includes the following functional components, which are described in "White Paper 1: String Battery Introduction" and "White Paper 2: String Battery Ecosystem" documents.

White Paper 1: String Battery Introduction

- Electric vehicle powered by string battery
- String cells

White Paper 2: String Battery Ecosystem

- Tanktwo Cloud
- Manufacturers
- Cell stations
- Maintenance and repair service providers
- Banks and global payment solutions
- Electricity utilities and trading platforms
- E-waste recyclers
- Networking

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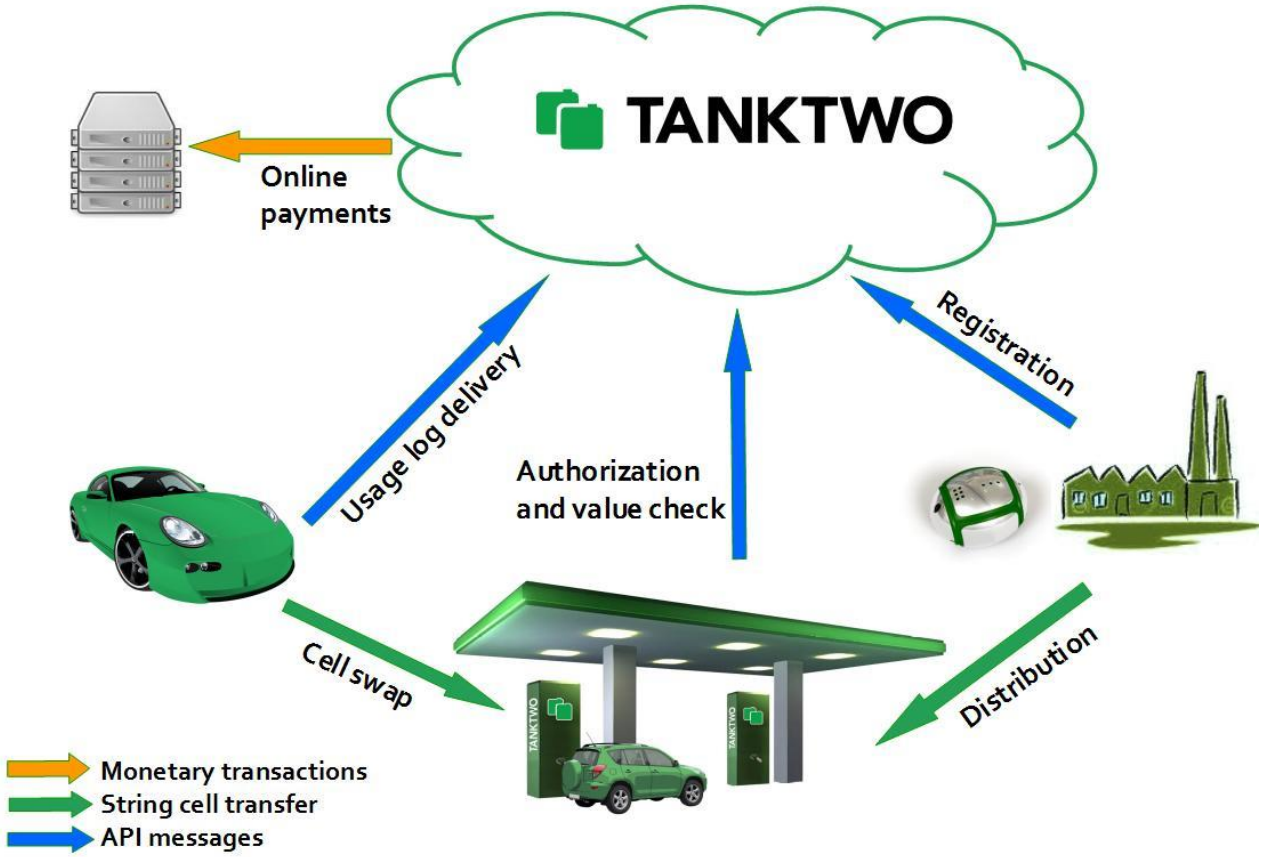

Figure 2: Most important components of the Tanktwo string battery ecosystem

Figure 2 shows the most important components of the Tanktwo string battery ecosystem and the relationships between them.

To achieve the functionality requirements of a global scale ecosystem we have designed the ecosystem from the beginning with security as the prime design factor. The security design of the Tanktwo ecosystem is divided between information security and physical security. Information security of the system is achieved by analyzing each component in regards to confidentiality, integrity and accountability, a model commonly known as the CIA-triad. The security solutions required by the ecosystem are based on existing and proven cryptographic solutions that are widely used in similarly scaled interconnected systems.

Tanktwo Cloud

The Tanktwo Cloud is the back-end storage and processing platform for all the string cell related data. The Tanktwo Cloud provides string cell information, data collecting and usage data analysis services to the applications which need to verify the string cell identity and remaining value. It also provides graphical user interface service to string cell owners and users. The Tanktwo Cloud consist of three logical entities: User interface server, string cell register and string cell usage data analyzer.

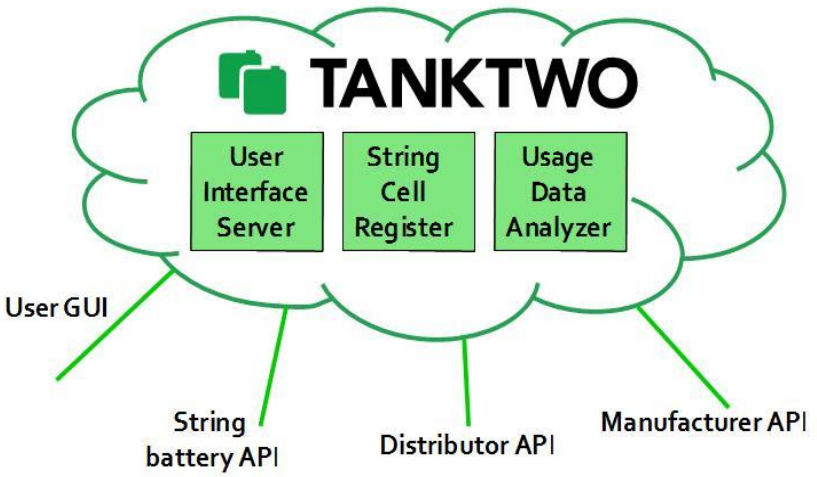

Figure 3: Tanktwo Cloud internal structure and external interfaces

When new products in the Tanktwo ecosystem, like string cells, string batteries or cell stations are taken into use, they need to be registered to the Tanktwo Cloud. The Tanktwo Cloud provides manufacturer application interface which authorized manufacturers can use to register new products. This registration ensures that each device in the ecosystem can be reliably identified and communicated with over insecure communication channels, such as the Internet. (Read more about communication solutions in Networking-chapter). The Tanktwo string cell register and usage data analyzer are essential components of an ecosystem which fosters system reliability and trust between parties. The string cell register provides authentication and authorization services, which enables distributors to reliably identify string cells. Within the string cell register database, each string cell's authentication information is securely stored. Those that require this information (for example, cell stations during cell swaps) can access these authentication and authorization services through the distributor application interface. The string cell register also stores string cell profiles which define the usage limits for each string cell. These string cell profiles contain, for example, maximum charging and discharging currents, operating temperature limits, etc. Using these profile parameters, manufacturers can define the safe usage range of a particular string cell. Figure 4 presents an example of different types of string cell profiles. String cell owners can define an even

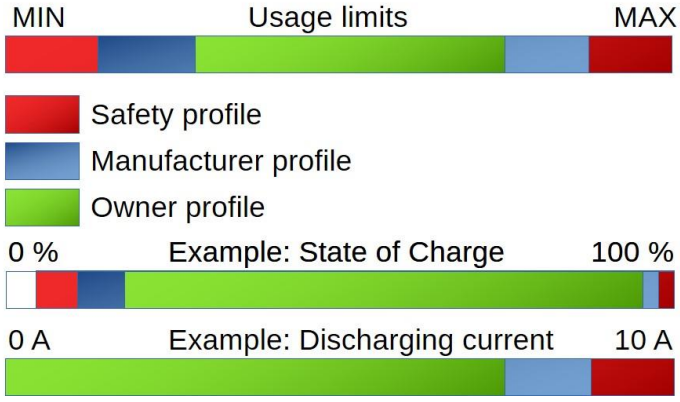

Figure 4 - String cell profiles determine the usage limits

narrower range for each charging cycle, which extends the life of each string cell and affects the calculated string cell value while swapping string cells.

The string cell usage data analyzer service, which the Tanktwo Cloud provides, is based on string cell usage history information like voltage, current, temperature, internal resistance and charge cycles, which is collected almost in real time from every string cell. String batteries and cell stations periodically send this usage log information to the Tanktwo Cloud using the string battery application interface.

Lifecycle index
Lifecycle index is a percentage value, which estimates the remaining lifecycle time of the string cell. For example if the lifecycle index value is 50 % it means that the string cell is in the middle of its lifecycle.

Fair market value
Fair market value is an estimate of the current resell value of the string cell. Fair market value is calculated using the lifecycle index and string cell market value data.

The Tanktwo Cloud's string cell usage data analyzer function is evaluating the string cell lifecycle index value by comparing the usage history data to the reference data defined by the string cell manufacturer, as illustrated in the Figure 5. The lifecycle index value together with market value feedback can be used to determine fair market value for every string cell.

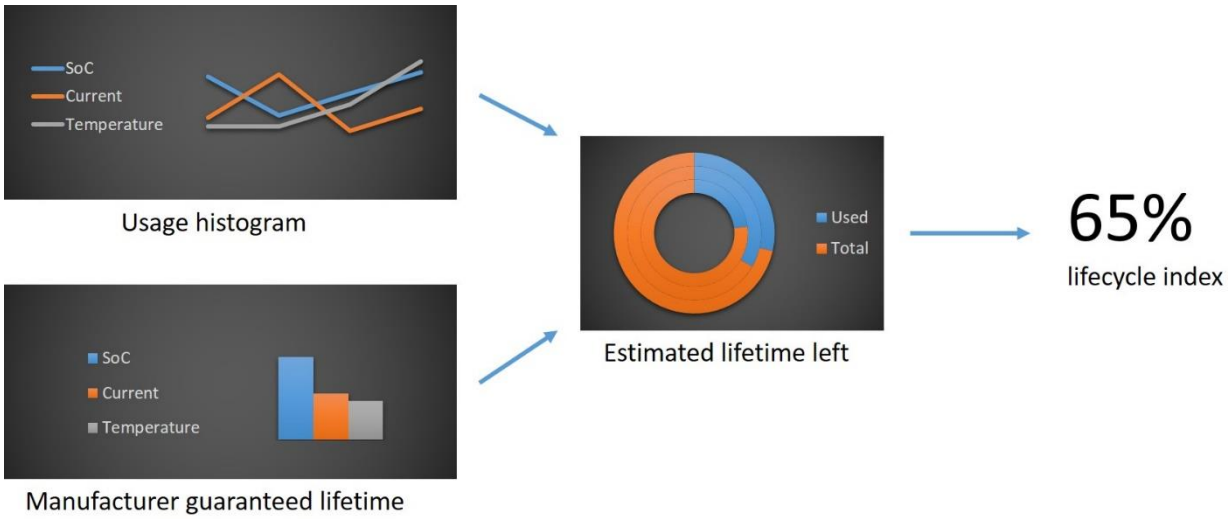

Figure 5- Lifecycle index estimation is based on usage history data and information supplied by the manufacturers

In the Tanktwo solution the user interface server implements graphical user interface services for the string battery owner and EV user. This GUI is availed both via web browser or native smart phone application. It provides tools to monitor string battery, modify string cell profiles and control string cell swaps, from the comfort of their smartphone or other internet connected device. In addition to the web GUI the ecosystem makes it possible for electric vehicle manufacturers to integrate a local user interface, which can be used to monitor the string battery status from the vehicle infotainment system without any internet connectivity. Combined with internet connectivity, this vehicle user interface can also be used to control the string cell swaps.

The Tanktwo Cloud is designed to be efficient and scalable to support millions of EV users, including

billions of string cells. Data is stored in a data structure solution that optimizes the needed storage capacity and computational power. Data is transferred using compression techniques that minimize the bandwidth needed between the Tanktwo Cloud and clients like string batteries or cell stations. Big data solutions, which allow parallel processing and distributed hosting, are used to guarantee fast response times and reliable service for the clients.

Tanktwo Cloud is designed to secure the data stored within the databases. The interfaces described above allow controlled access to data, i.e. the client's access is limited according to predetermined rules. Good data storage practices, such as the encrypted storage of credentials, and distributed storage solutions (that ensure accessibility and multi-level user management) are applied, which limits access to the information and operations granted to that particular user. A dedicated firewall and intrusion prevention systems protects the data storage from malicious attacks and other events that would compromise the security of the system.

Manufacturers

String cell manufacturers play several important roles. First and foremost, they must provide supply of string cells for distributors who then sell to users, cell stations, car dealers or EV repair shops.

Secondly, string cell manufacturers play an instrumental role in string cell software and hardware development. Tanktwo defines the functional requirements necessary to guarantee the compatibility between string cells from different manufacturers. This system is also designed to allow easy adoption of new battery cell technologies, as well as new string cell versions which change the number of contacts, internal computing solutions, etc. As long as certain requirements for communication, size and performance are met, the adaptive, modular unit construction allows for different types of string cells to be used within the same string battery.

Manufacturers are also needed to produce other physical components like string batteries and cell station infra (i.e. string cell swapping, transportation and storage solutions). String cell battery manufacturers work in close co-operation with EV manufacturers to design suitable string batteries for each EV model.

Various manufacturers are given access to Tanktwo Cloud's manufacturer application interface for product registration, activation and monitoring. Depending on the type of product, as well as the manufacturer-specific requirements, the interface may be customized for easy integration to each manufacturer internal management systems.

Tanktwo will define the safety, quality, environmental standards and codes of conduct that all manufacturers must follow. These standards will adhere to the highest level of responsible accountability to both the environment and the consumer.

Cell stations

Within the Tanktwo ecosystem, cell stations fill an important role. They provide automatic refilling opportunities for EVs, which can take place without the user exiting the vehicle. Cell stations possess the string cell swapping solution, which transports the empty string cells from the string battery, and replaces them with fully charged string cells.

The string cell swap procedure can even start before string cell powered EV arrives at the cell station. When an EV user notices that string cells are running out of power and string cell swap is needed, user can access the owner GUI via smartphone or the integrated vehicle interface to fetch swap offers from the nearest or favorite cell stations. The user interface server in Tanktwo Cloud sends the swap offer request to the selected cell stations. Based on the string cell information that the cell station received from Tanktwo Cloud it can calculate the offer, which is then passed on to the user. Based on received offers user makes decision into which cell station to go to.

When a string battery powered EV arrives at the cell station and the driver stops the car on top of the automated swapping device, a swapping duct connects to the vehicle's string battery. Then, the cell station and string battery authenticate each other. If the authenticity of both parties can be verified, the cell station gives the user the final price for the exchange. Ones the user has accepted the offer, the online payment gateway checks the user's payment option and verifies the funds. After the payment information is verified, the swapping device starts moving the string cells from the user's string battery to the cell station. When the string battery is empty, the cell station moves the charged string cells to the string battery. The user has the option to cancel the swapping at any time and his string cells are returned to the string battery. After a successful string cell swap, the new string cell ownership data is updated within the Tanktwo string cell register database.

The cell station has the ability to separate broken or fraudulent string cells from good ones. String cells that are moved to the cell station are analyzed individually. If any of the string cells are identified as differing from the information given to the cell station during the swapping process, the string cell can be returned to the user or the exchange price can be altered afterwards. After the analysis process, the reusable string cells are moved to a charging unit and then on to storage silos. The string cells can be separated into different silos according to their quality, allowing the user to choose string cells within a certain (desired) quality category.

Maintenance and repair service providers

Within the Tanktwo ecosystem, 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 cell station where cell swapping 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.

A string battery can be opened at the maintenance outlet by a technician, after which the string cells are removed with a portable swapping device. This device analyzes the status and health of the removed string cells, similar to the analysis process at the cell station, 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 underperforming cells with new ones, if the capacity or performance of the string battery is to be restored.

Checking of the string cell status is also possible without the swapping device. String cells can switch on an indicator LED which displays a green light if everything is OK, and red light if the string cell is experiencing malfunction. When the technician has opened the string battery he can order the string battery management unit to send a command to every string cell to switch the indicator LED on. String cells with green light are OK and string cells with a red light, or no light at all, are easy to separate manually for further analysis. The integrated wireless communication and processing power inside the string cell, as well as the usage history information collected by the Tanktwo Cloud enables extensive analysis to be conducted by the technician, which makes it possible to pinpoint problems in the system remotely.

Banks

Banks provide a reliable and trusted channel for money transactions related to string cell buying, swapping and re-selling. Banks may also provide consumer financing services for the purchase of the initial parcel of string cells when purchasing a new electric vehicle.

The Tanktwo Cloud uses a 3rd party online payment gateway solution for payment transaction handling. Online payment gateway provides for the user many different payment methods like local bank card, international credit/debit card, online banking or PayPal.

Electricity utilities and trading platforms

Electricity utility companies provide the necessary electric power to cell stations and consumers. For the cell stations, it is crucial to get the electric power at the cheapest possible price in order to optimize the price offering for string cell swapping and maximize the profit.

Cell swapping offers possibilities for storing electricity when there is an excess supply on the market, i.e. when the price is low. This helps the cell stations increase profits by charging string cells when the electricity is cheap, but also helps the electricity grid to survive from sudden peak loads. Cell stations work as large electricity storages, which can be integrated with the electricity grid. Combined with the easy service of the string batteries, this surpasses any current solution for distributed energy storage.

E-waste recyclers

When string cell reaches its end of life it must be disposed of properly. E-waste recyclers have

specialized to dispose and recycle electric components and batteries. Electronic recycling occurs primarily in order to recover valuable rare earth metals and precious metals, which are in short supply, as well as plastics and metals. In case of string cell the internal electric components and the shell can be easily recycled, given the homogeneous shape of the string cell which simplifies the recycling process greatly, compared to general battery pack recycling process. If the lithium battery cell of the recycled string cell has some storage capacity remaining it can be recycled to some second-life battery application, which has lower requirements compared to the EV usage.

In the case of the string cells which contain lithium-based batteries it is not at the moment commercially viable to recycle the lithium material. As Lithium deposits are at the moment widely available, spent lithium batteries have little commercial value and there is a price to recycle. The true cost to manufacture a lithium battery is not so much in the raw materials, as is the case with lead acid, but in the lengthy preparation, purification and processing of the raw material. Recycling brings the metal to ground zero from which the preparations must begin anew. It is often cheaper to mine the raw material than retrieve it from recycling.

Networking and security

Tanktwo's network interfaces offer access to the ecosystem via internet. These interfaces are used by different ecosystem parties to exchange information and enable string cell management. Examples of the network interfaces' management capabilities include: registration of new string cells prior to use in the string battery, providing cell stations with the reliable information they need to distinguish between fraudulent and authentic string cell values (necessary to determine the exchange value) and allowing individual users to access the Tanktwo Cloud to query the data for string cells he/she owns. Tanktwo network interfaces are designed to be easily incorporated into existing systems and communicate reliably in a secure way that prevents any malicious system usage.

To integrate the String Battery into electric vehicles Tanktwo has defined internal interfaces, which offer bi-directional communication between the control units in the vehicle and the battery. This enables the battery to receive accurate information and adapt to the current driving style and conditions. Users can interact with the string battery using the user interface, which offers status updates of the string battery and information on the electricity consumption of the EV.

To ensure safe and secure operation between Tanktwo Cloud and the client, encryption and authentication methods are implemented. These solutions are customized based on the type of client and data that is accessed. Additionally, compression methods are used to minimize the bandwidth needed for data transmission through the communication network. This process facilitates the usage of mobile network connections when accessing the Tanktwo Cloud.

Tanktwo Cloud also offers string cell owners the possibility to monitor the string cells and modify the operating parameters. This allows users or companies to manage the capacity and usage of the cells and receive fair market value estimate from the string cells owned. Depending on the type of

data and the client, the implementation of security and compression can vary. For example, a manufacturer registering a new batch of string cells has an isolated connection to Tanktwo's high security datacenter. String batteries may use a slower, less reliable mobile network to transmit data from thousands of string cells using high-rate compression and buffering capabilities.

Interfaces between other communication networks, such as the in-vehicle network and the string battery, are designed to be reliable and resistant to malicious activity. Multiple attack vectors are analyzed during the ecosystem design and the system is hardened to defend against intentional or accidental attacks directed towards the string battery's communication system.

During the registration, the Tanktwo Cloud uses its internal cryptographical solutions to derive the identification, encryption and authentication keys, which are then stored securely in the Tanktwo Cloud string cell register. The applicable parts of these keys are handed to the manufacturer during the registration process over a secure channel. This operation enables trusted communication between any parties in the ecosystem.

Each string cell, cell station and string battery contains a unique identification code, as well as a corresponding authentication key. The identification code is used to identify the unit from the ecosystem network, as well as to route messages to it across the communication networks. The authentication key is used to verify that the unit identification is genuine. This ensures that the usage history information sent by a string cell can be reliably linked to that specific unit.

Encryption keys stored in the units and the Tanktwo Cloud are used to establish asymmetric encryption between the end-points. This solution prevents the usage information, as well as profile settings and other data to be viewed by other unauthorized parties. The included signature-portion also prevents the manipulation of data during transmission. Secure and reliable string cell identification and authentication is required to prevent fraudulent string cell usage and to verify authenticity during the string cell swap. This process authenticates the firmware, usage history and profile settings, which instills trust in the battery usage data analysis resulting string cell lifecycle index and fair market value.

Tanktwo's string cell design is tamper resistant; the data stored within its internal memory is secure. Authentication credential data is not directly accessible, preventing string cell cloning. Log information is collected during the string cell's normal operation and stored in protective memory within the string cell. The logging information used for the string cell usage data analysis is protected against overwriting. This ensures that the string cell usage pattern can't be changed prohibiting alteration of the sting cell's exchange value.