Evaluation of a PV Powered EV Charging Station and its Buffer Battery

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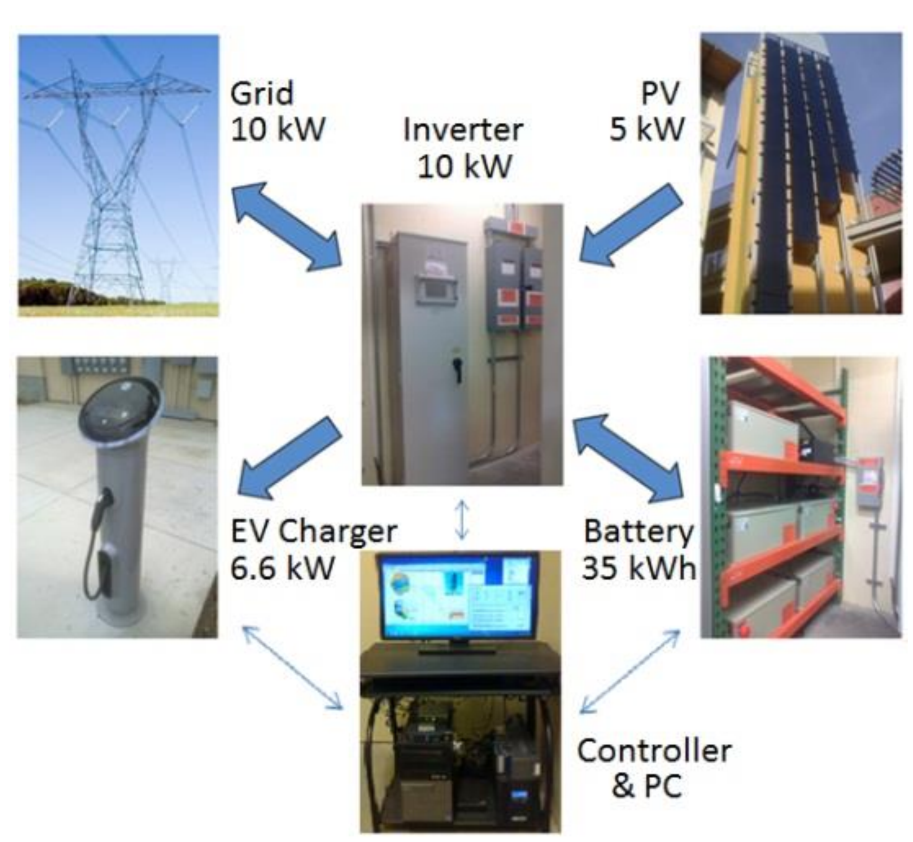
Project Background

Most of EVSEs are connected to the grid directly, which incurs the high cost of demand charges caused by spikes in power usage, often a barrier to installing EV changing stations. Demand charges are part of every commercial electricity bill and are determined by the highest 15 minutes of use during a billing cycle. In California, rates can skyrocket during midday periods of high demand in summer. Some solar PV-Powered EV charging stations (PV-EVSE) can reduce high power demand during peak times, but are subject to the change of the weather. Battery-integrated EVSEs can significantly smooth the charging spikes and mitigate charging from on-peak time to off-peak time. Combining EV charging equipment (EVSE) with an energy storage system (ESS) and solar PV eliminates the high cost of demand charges caused by spikes in power usage and maximizes the usage of renewables locally. Using storage batteries and solar PV panels with intelligent energy management system reduces the energy exchange with the grid, manages and smooths EV charging demand spikes, and avoids high demand charges during on-peak time periods. A solar PV powered EV charging station with energy storage (PV-ESS-EVSE) may be more efficient and economical compared to a solar PV-integrated EV charging stations (PV-EVSE) and a charging station with buffer battery only.

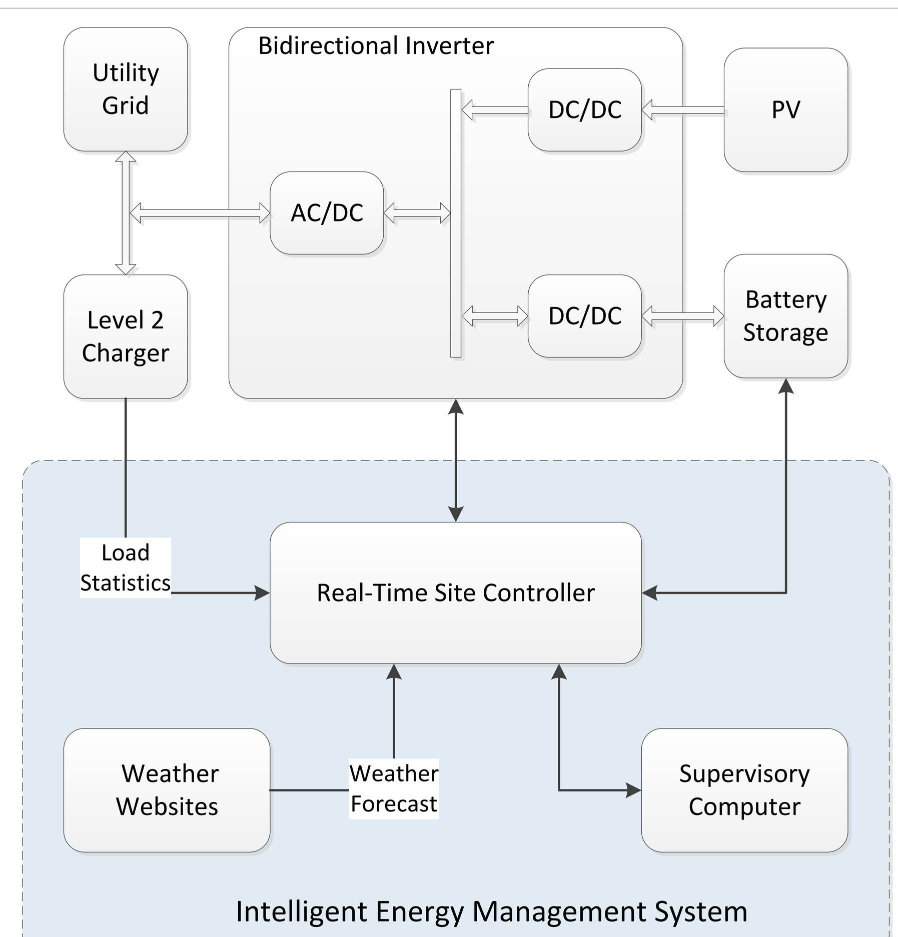
Project Objective

A PV-ESS-EVSE system has been developed and demonstrated at the University of California – Davis, West Village, the largest planned zero-energy consumption community in the U.S. The solar PV electrical energy forecasting and EV charging demand projection are introduced to the energy management system to optimize the state of charge (SOC) of the buffer battery, maximize the usage of PV electricity for EV charging, and avoid EV charging during peak hour time. The charging station has been operated continuously and used by several EV users for 20 months. This research collects data from both the battery management systems (BMS) and the real-time controller for assessing the control strategy and the system operation, and evaluating the cell consistency of the buffer battery.

Charging System and Control



Charging Station System



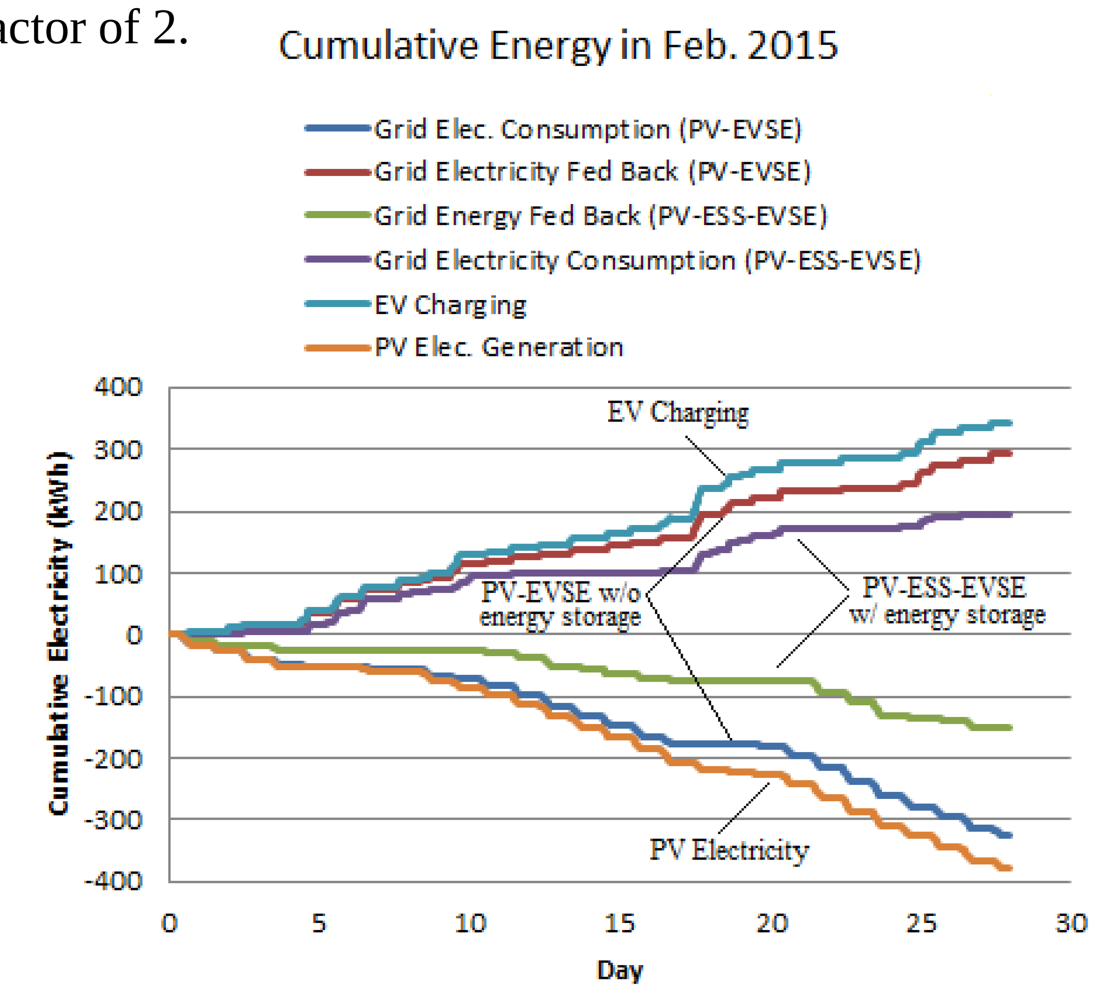
Charging System Block Diagram

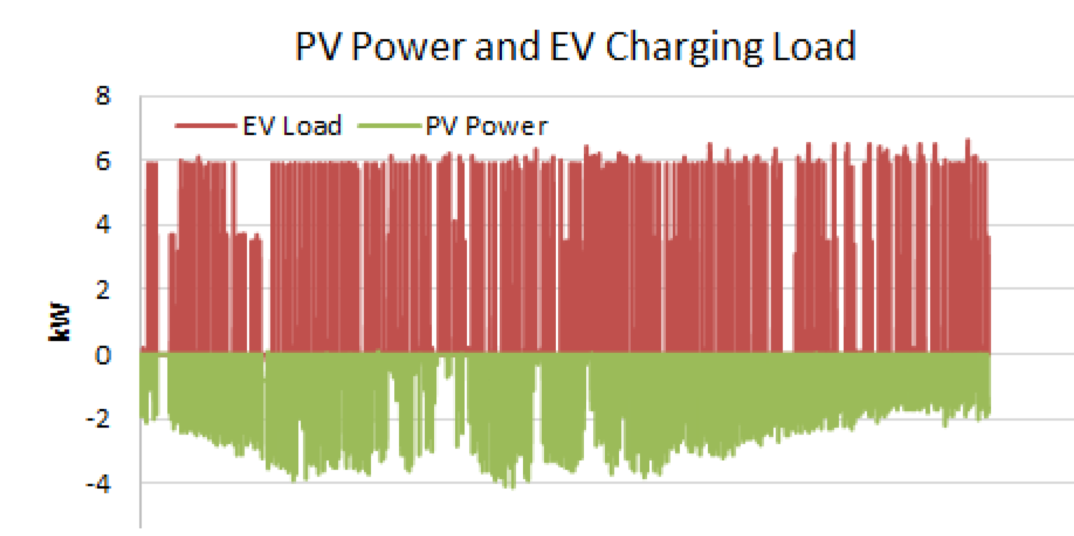
The power flow control strategy is to maximize PV energy for EV charging and reduce energy exchange with the grid and peak power demand from the grid. Aggregated EV charging demand on a certain day is projected by using similar-day-of-week approach, which is based on collecting and searching historical EV charging. The cloud cover is extracted from OpenWeatherMap and used for forecasting solar electricity. The battery SOC is optimized at a level dependent on the estimated PV energy generation and the projected EV charging demand.

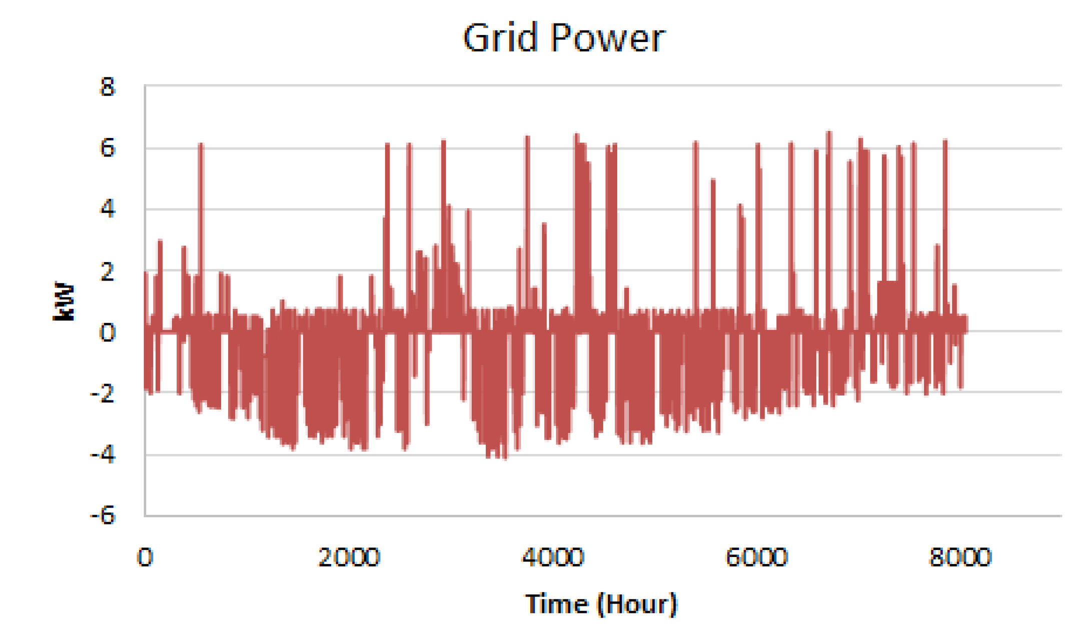
* Hengbing Zhao, Andrew Burke, Journal of Energy and Power Engineering, 2016. Vol.10, No.2, 121-128.

Charging Station Operation Assessment

Using a PV-ESS-EVSE system has some notable synergies with benefits to both the charger users and operators. The energy storage can buffer and localize solar PV electricity for EV charging and reduce EV charging power demand from the grid during peak-demand periods. The operation indicates that a PV-ESS-EVSE system with intelligent energy management can almost eliminate the station's peak power demand and reduce the energy exchange with the utility grid by a factor of 2.

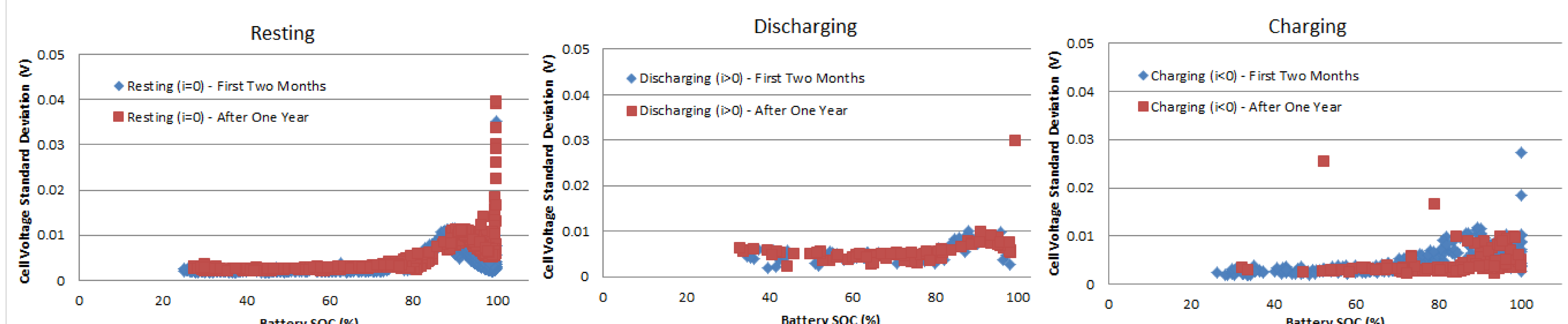




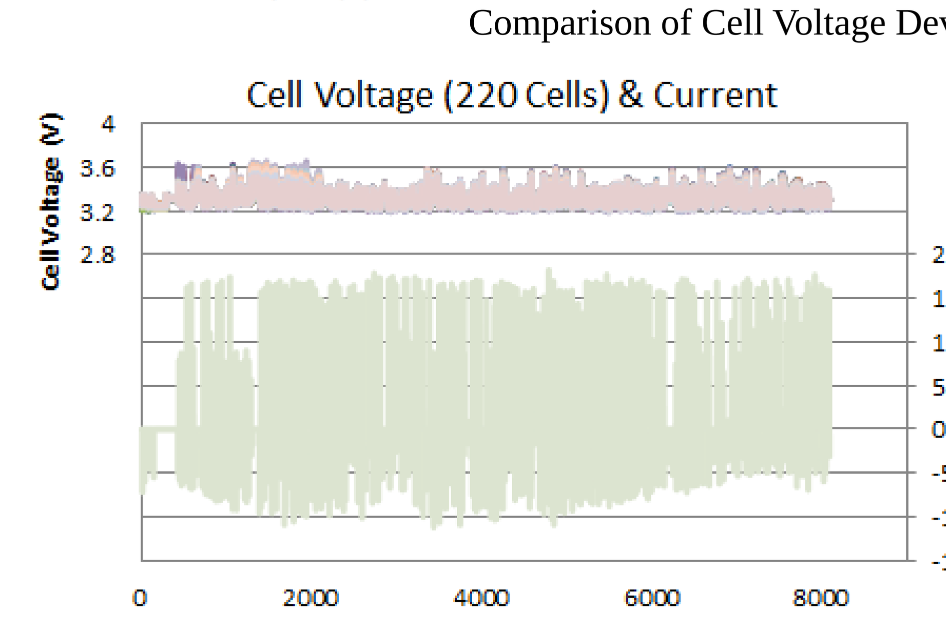


Battery Performance Evaluation

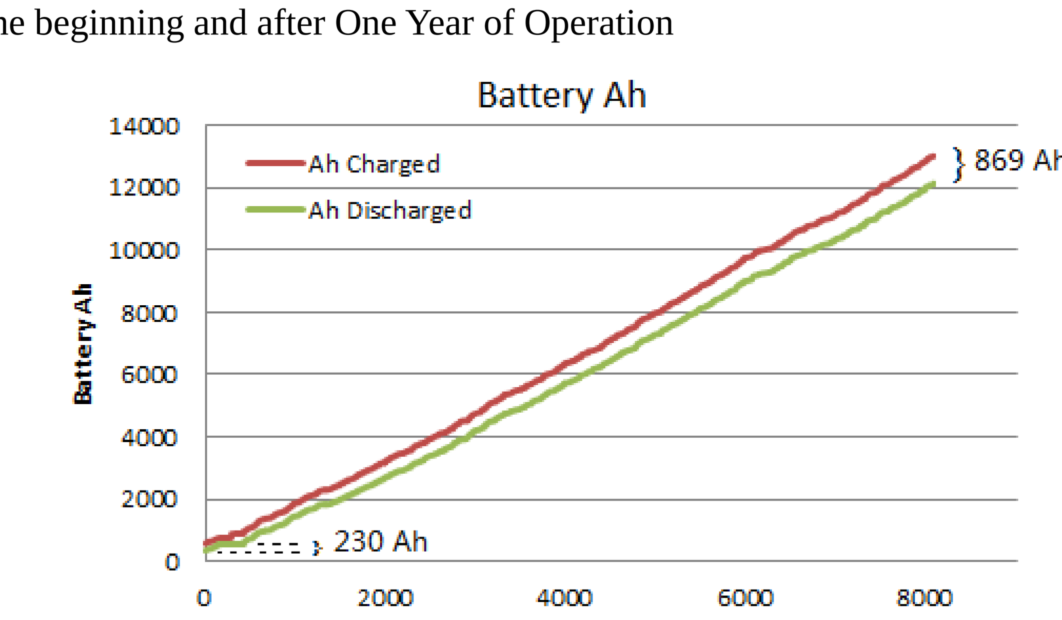
The performance of the buffer battery is evaluated on a pack and cell level after one year of operation. The 220 50Ah-cells are managed and balanced by 6 slave BMSs and a master BMS. The cell voltage deviation is calculated to evaluate cell voltage consistency and its deterioration, and battery self-discharging.



Comparison of Cell Voltage Deviation at the beginning and after One Year of Operation



Cell Voltage and Current



Battery Ah Charged/Discharged

- ❑ The 220 cells show excellent voltage consistency with voltage deviation of less than 5 mV for the cells with SOC between 20-80%. The voltage deviation doubles when the battery SOC reaches 90%.
- ❑ There is no obvious consistency deterioration during the battery resting, charging and discharging periods after one year operation.
- ❑ The loss due to self-discharge is 639 Ah over 8086 hours, which indicates that the average self-discharging current of the battery pack is 79 mA and the self-discharge is 1.9 percent per day.

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