Fast Charging Stations - Power and Ancillary Services Provision

Ivan Pavić, Tomislav Capuder, Igor Kuzle
University of Zagreb, Faculty of Electrical Engineering and Computing

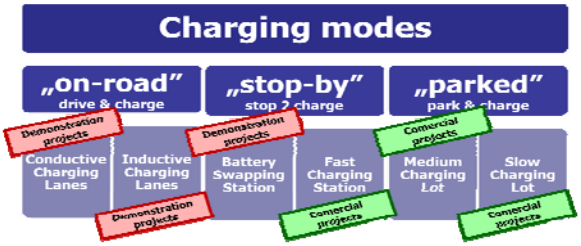
1. Introduction

Increasing number of variable and renewable energy sources (RES) creates new operation paradigm for power system operators. Sudden changes in RES generation along with unpredictable nature of RES primary source give rise to greater flexibility and operation reserve requirements. There are two distinct ways how to increase flexibility of the system. The first one is to invest in new flexible power plants such as gas power plants but their integration oppose the idea of carbon-free modern power system. The second way is to use new concepts and technologies such as microgrids, battery storage, demand response, electric vehicles…This paper will define how and when can electric vehicles provide flexible options such as controllable charging, discharging and reserve provision.

2. EV charging modes

Electric vehicles, in contrary to their internally combusted counterparts, possess a wide range of possible charging modes. Interdependency of EV's charging and driving/parking processes can be described through three main modes:

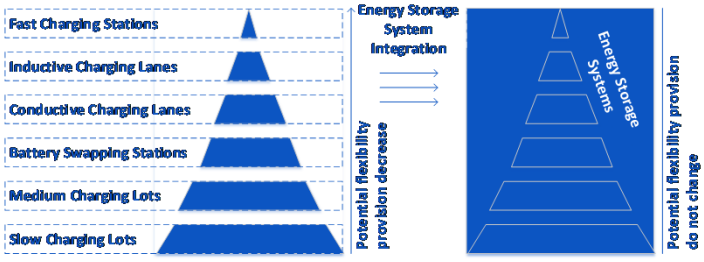
- **„On-road charging" or „drive & charge"** modes: driving and charging at the same time through infrastructure installed at roadways;
- **„Stop-by charging" or „stop 2 charge"** modes: driving with brief stops for charging through infrastructure installed next to roadways;
- **„Parked charging" or „park & charge"** modes: parking and charging at the same time through infrastructure installed at parking lots.



EVs charging modes

3. EVs and system's flexibility

Charging modes can act either as flexibility sink or as source. Parked charging modes, due to their low power ratings and long connection time, can be charged in a controllable manner and provide flexibility. Battery swapping stations do not charge EV directly from the grid, they charge the stack of the swap-available batteries. Therefore, the stack can be seen as a mediator between the grid and the EV and the station can act as a flexibility source. Charging lanes, in theory, are primarily used for driving so they can charge EVs controllably which can provide flexibility to some extent. Fast charging stations are the lowest when flexibility provision is in question because EV users want to charge their vehicle as fast as possible and to move on with their activities. Flexibility for each of those modes can be improved by energy storage integration, especially for fast charging stations.



EVs flexibility impact

4. Model

In order to define possible flexibly provision from EVs system composed of thermal, hydro and wind power plants, conventional demand and EV has been established. Main equations in power system UC modeling are power-demand and reserve provision-requirements constraints:

$$\sum_{i=1}^{Ni\_TP}\left(p_{t,i}^{g\_TP}\right)+\sum_{i=1}^{Ni\_HP}\left(p_{t,i}^{g\_HP}\right)+\sum_{i=1}^{Ni\_PS}\left(p_{t,i}^{g\_PS}-p_{t,i}^{p\_PS}\right)+p_{t}^{g\_WP}=$$

$$=P_{t}^{d}+\sum_{i=1}^{Ni\_EV}\left(p_{t,i}^{c\_EV}-p_{t,i}^{d\_EV}\right)+\sum_{i=1}^{Ni\_FCS}\left(p_{t,i}^{c\_FCS}-p_{t,i}^{d\_FCS}\right)$$

$$\sum_{i=1}^{Ni\_TP} r_{t,i}^{up\_TP}+\sum_{i=1}^{Ni\_HP} r_{t,i}^{up\_HP}+\sum_{i=1}^{Ni\_EV} r_{t,i}^{up\_EV}+\sum_{i=1}^{Ni\_FCS} r_{t,i}^{up\_FCS}\geq R_{t}^{up}$$

Electric vehicles have been observed as:

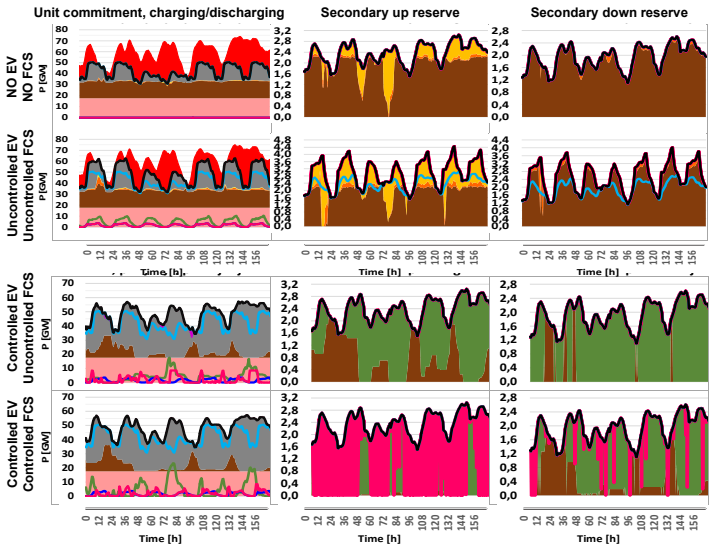
- Aggregated battery of the whole EV fleet;
- Variable capacity battery → on-grid EV number is not a constant;
- SOC is influenced by driving/charging/discharging processes;

Energy conservation of EV is modeled by:

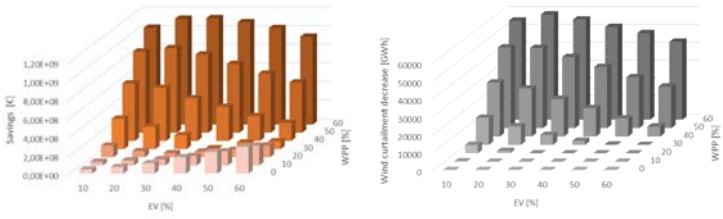
$$s_{t,i}^{\_EV}=s_{t-1,i}^{\_EV}+s_{t,i}^{arr\_EV}-s_{t,i}^{leav\_EV}+p_{t,i}^{c\_EV}*\eta_{i}^{c\_EV}*\Delta t-p_{t,i}^{d\_EV}/\eta_{i}^{d\_EV}*\Delta t+s_{t,i}^{add\_FCS}$$

5. Results

Impact of fast charging stations and slow charging lots as extreme modes in regards to flexibility is presented on diagrams bellow.



EV and FCS impact on unit commitment and reserve provision



Savings and wind curtailment for different wind and EV levels

6. Conclusion

Smart, controllable EV infrastructure with its flexibility can minimize costs for grid and generation investment which can occur due to:

- EV integration („dumb" infrastructure)
- RES integration;