Master project, 2022-2023

— Modeling and power management of EVs charging station powered by PV-based DC microgrid —

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Context

In France, the energy consumption of transports sector represents nearly 30% of the final energy consumption and nearly 40% of greenhouse gas emissions, where 95% is emitted by road transport. It is the only sector whose emissions have increased continuously since 1990 [1]. Therefore, the reduction of air pollution and the decarbonization of transports these are social issues that the public authorities have largely taken up, in particular by promoting alternatives mobilities. Under this impulse, electric mobility is particularly supported throughout the territory. However, the increase in the number of electric vehicles (EVs) within the rolling stock will induce an increase in power demand due to new charging needs, while the power grid was not designed to withstand consumption peaks caused by the simultaneous recharging of millions of EVs. Moreover, the environmental benefits of EVs depend on how the electricity that powers them is produced [2, 3]. To reduce the EVs impact and enhance their environmental benefits, this energy transition should pass through the multiplication of photovoltaic (PV) installations. However, the intensification PV energy production reveals an increasing complexity for the power grid operators caused by the intermittent character. Focusing on the transport sector, the intensive use of PV energy sources should be combined with the needs of EVs charging. Thus, it is necessary to adopt a systemic approach for global optimization under constraints by integrating aspects related to the PV intermittency, uncertainties related to the availability of charging terminals and the parking time of EVs, and the price of electricity. In this framework, the concept of intelligent microgrid, based on PV sources, stationary storage, and connection to the public grid, is an effective and reliable option to consume the PV production on site with an intelligent and efficient way. This is the context of this master project. He is interested in the sector of electrical micro-grids based on PV installations and dedicated to charging EVs. A management algorithm will be developed to optimize the power flow in accordance with the requirements of EVs users, while respecting the physical limits of the public grid and the elements of the PV-powered charging station (PVCS).

Objectives

This master project will address the aspects related to the integration of PV generators and EVs in smart electrical networks, with a particular emphasis on the aspect of power management. The goal is to define the feasibility conditions for PVCS in order to satisfy the need of EVs in an urban area.
In this framework, a two-layer power management algorithm will be developed to manage the power flow in the PVCS leading to increase the participation rate of the PV production for EVs charging. The first layer will be dedicated to modulate the charging power profile of each EV. It will receive as inputs the characteristics of each EV communicated by users (initial state of charge (SOC), SOC desired at departure, parking time, etc.). The second is the operational layer of the microgrid which will be responsible for maintaining the instantaneous power balance at the common DC bus of the micro-grid, with the consideration of the physical constraints and limits of the system (grid power limits, limits of power and SOC of the storage system). This layer will modulate the reference powers to be exchanged with the public grid and the stationary storage system and will perform PV or EV shedding when necessary. In addition, a calculation method of energy distribution will be suggested to estimate the participation rate of each source for the charging of EVs.
Several scenarios, based on the charging mode and the knowing of the parking time, will be proposed for a PV parking shade with five spots and five chargers, in order to assess the benefits of the PV for the PV-powered EVs charging station.

Work steps

In a first time, the candidate will be required to present a state of the art on EV charging infrastructures powered by PV installations, as well as the controls associated with each element of these infrastructures. In addition, a bibliographic study on the theory of power management of multi-sources systems will also be carried out.
In the next step, the candidate will develop a model simulating an EVs charging station based on DC microgrid and composed by PV source, a stationary storage system (battery), a connection with the public grid, EV charging terminals, and a common DC bus. This model will meet the demands of EV users while improving PV benefits.
Once the model will have validated under MATLAB/Simulink software, the two-layer power management algorithm will be developed to manage the power flow in the PV-powered charging station leading to increase the participation of

the PV system for the charging of EVs and encourage users to recharge their EVs at the right time by favoring periods of PV production.

Key words

Electric vehicles; photovoltaic; charging station; power management; microgrid.

References

[1] Le réseau de transport et d'électricité, RTE. Enjeux du développement de l'électromobilité pour le système électrique, mai 2019.

[2] IEA PVPS, Task 17, PV and Transport. PV-Powered Electric Vehicle Charging Stations Preliminary Requirements and Feasibility Conditions. 2021, ISBN 978-3-907281-26-0, pp 1-160.

[3] Krim, Y.; Sechilariu, M.; Locment, F.; Alchami, A. Global Cost and Carbon Impact Assessment Methodology for Electric Vehicles' PV-Powered Charging Station. Appl. Sci. 2022, 12, 4115. https://doi.org/10.3390/app12094115.