

## Research context and motivation

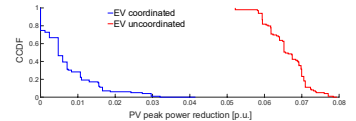
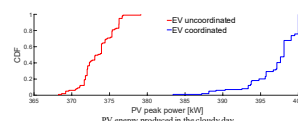
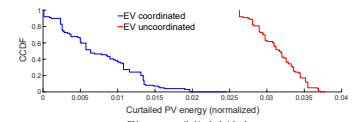
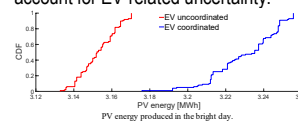
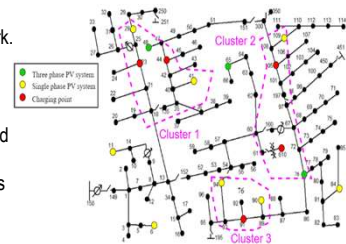
- The exploitation of renewable energy sources (RES) is a viable option to reduce the harmful impact of the greenhouse gas emissions resulting from the use of fossil fuels as the primary source of energy generation. Photovoltaic (PV) plants are the dominant type of RES connected to the Medium Voltage (MV) or Low Voltage (LV) grids. The reduction in the production cost and the increase in the PV module efficiency enable progressive PV diffusion. On the global scale, the diffusion of PV plants is still limited, compared with the overall electricity needs.
- The lack of grid capacity to receive the excess power input from PV systems could require PV generation curtailment and prevents the distribution grid from reaping the full benefits of using the PV energy, especially in mid-day hours of bright days. Besides all, renewable energy directives of Europe emphasize on the increasing of renewable energy resources as reliable source of energy in the future.
- In this framework, a novel smart charging strategy for electric vehicles (EVs) operated in the grid-to-vehicle mode is defined, based on clustering and fuzzy weights. This strategy is applied by using the blockchain technology with a Proof-of-Authority consensus protocol to reinforce network security and reach decentralization, while providing full transparency and traceability of the EV charging operations and grid status monitoring during time. using battery energy storage systems (BESS) still is not convenient because of relatively high costs of such systems, but EV batteries could potentially be considered to store the excess energy generated by RES by means of the charging managing system proposed in this work.

## Novel contributions

- Mitigating photovoltaic energy curtailment through smart charging of EVs** : using the excess energy produced by the PV system, and the EV charging power is managed through a strategy based on fuzzy weights.
- Increasing the capacity of clean energy generation** : the proposed methodology could lead in the increase in the production of RES by means of energy curtailment reduction and reducing grid constraints such as line overloads and voltage violations.
- This strategy is applied by using the blockchain technology** : distributed ledger technology (DLT) reinforces network security and ends up in reaching decentralization, while providing full transparency and traceability of the EV charging operations and grid status monitoring during time.
- Novel indicators of avoided PV power reduction and energy curtailment for the uncertainty assessment** : they are determined from a Monte Carlo-based assessment of the three-phase power flow results to account for EV-related uncertainty.
- Interoperability** : The proposed approach can be used with any type of generation, load or storage connected to the grid.

## Adopted methodologies

- IEEE 123 bus system has been adopted for this work.
- EVs increase their charging power according to a Selection mechanism based on fuzzy logic.
- Fuzzy weights will be assigned to EVs using their state of charge (SoC), loading percentage of line and the PV production.
- The selection mechanism takes place inside clusters which are made based on the K-means clustering technique with electrical distances.
- Novel indicators of avoided PV power reduction and energy curtailment are defined and are determined from a Monte Carlo-based assessment of the three phase power flow results to account for EV-related uncertainty.



| Cloudy day       | $\bar{W}_{PV,cur}$ | $\xi_W$ | $\xi_{LP}$ | $\xi_{LP,5\%}$ |
|------------------|--------------------|---------|------------|----------------|
| EV uncoordinated | 37.5 kWh           | 0.828   | 0.939      | 0.874          |
| EV coordinated   | 8.7 kWh            | 0.834   | 0.987      | 0.924          |

| Bright day       | $\bar{W}_{PV,cur}$ | $\xi_W$ | $\xi_{LP}$ | $\xi_{LP,5\%}$ |
|------------------|--------------------|---------|------------|----------------|
| EV uncoordinated | 102.9 kWh          | 0.969   | 0.938      | 0.872          |
| EV coordinated   | 25.7 kWh           | 0.992   | 0.993      | 0.931          |

$\bar{W}_{PV,cur}$  : The average PV energy curtailed     $\xi_W$  : Avoided PV energy curtailment effectiveness     $\xi_{LP}$  : PV peak power reduction effectiveness     $\xi_{LP,5\%}$  : PV power reduction effectiveness at 5%

## Future work

In the future work, clusters will be formed according to the loss allocation technique proposed in the "Investigation on the Loss Allocation Properties in Distribution Networks with Distributed Generation" paper. The impact of charging station and PV production will be assessed locally throughout energy communities.

## Publications

- S. Saadatmandi, G. Chicco, A. Favenza, "Exploiting Blockchain for Smart Charging of Electric Vehicles: A Proof of Stake Algorithm", BLockchain for Renewables INtegration (BLORIN 2022), Palermo, Italy, 2-3 September 2022
- S. Saadatmandi, G. Chicco, F. Giordano, "Reducing the Curtailment of Photovoltaic Energy Production through Smart Electric Vehicle Charging", 2022 114<sup>th</sup> AETI International Annual Conference, Rome, Italy, 3-5 October 2022
- A. Mazza, S. Saadatmandi, S. Safina, G. Chicco, "Investigation on the Loss Allocation Properties in Distribution Networks with Distributed Generation", 2023 58th International Universities Power Engineering Conference, Dublin, Ireland, 29 August – 1 September 2023

## Addressed research questions/problems

The solutions proposed to tackle PV generation curtailment typically fall into three major categories in the literature reviews :

- Development of control strategies to enhance the operation of PV systems by exploiting the active and reactive power control capabilities of the equipment available in the distribution network.
- Designing BESS suitable for managing the energy produced by RES.
- Adapting the intermittent demand to receive the excess of PV generation.

