D3.1 Physical Model of the Grid
Final Version

Deliverable

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ABOUT THE NEMoGRID PROJECT

The NEMoGrid Project is mainly focused on the definition of innovative business models that could ease the penetration of renewables into the distribution grid, with a particular emphasis on the definition of a peer-to-peer strategy based on the blockchain technology. The new business models will encourage the active participation of citizens and the assumption of their new role of prosumers, by allowing them to enter new markets as players. Among the tested scenarios, the most innovative one will be based on a peer-to-peer market. In this case, new decentralized platforms based on the blockchain technology will allow zero marginal cost transactions. In order to test the new business models effectiveness, a simulation framework will be developed. Each scenario will be evaluated base on a number of KPIs. Existing demo sites in Rolle and Lugaggia (CH), Björklinge (SE) and Wüstenrot (DE) will be used to validate the business model that gives the best simulation results. Real loads will be controlled by the algorithms developed in the simulation phase. Technical developments within NEMoGrid will be supported with user research, gathering empirical data on prosumers decisions and interactions. The results will be used to develop an adoption model and to continuously refine the simulations.

>> www.nemogrid.eu
**Scope and Test sites**

The Scope of the deliverable is to provide a simulation framework for the electricity grid of the test sites. The input data is gathered from two test sites of the Nemogrid project: Lugaggia (Switzerland) and Upsala (Sweden).

1.1. **Lugaggia**

Lugaggia is a village near Lugano, in southern Switzerland, hosting the Swiss test site in which the P2P local market is tested. The Lugaggia Innovative Community project (lic.energy) consists of a self-consumption community of 18 prosumers, a school, and a 50kWh central battery. In the community, 63kWp of PV is installed, and smart control is performed by steering the central battery, 10 heat pumps, and 7 electric boilers for domestic hot water.

In collaboration with the local DSO, the grid topology of the Lugaggia community has been fully mapped and reproduced in simulation using krangpower (described in Section 0).

1.2. **Upsala**

The Swedish test site is composed of two 300KVA substations in the grid of the customer-owned DSO Upplands Energi AB, situated north of Uppsala. In total, the two substations serve 132 households. Unfortunately, the topology of the grid served by the two substations was not available to the project partners. As a consequence, the simulation work focused on the Swiss test site.

**Electrical network simulation tool **Krangpower**

For load flow simulations, it was decided to rely on the open-source electric power distribution system simulator OpenDSS [01], which is fast and validated. However, OpenDSS is written in Delphi, while the simulation environment developed in the framework of the NEMoGrid project is written in Python . Therefore, to integrate OpenDSS in the NEMoGrid simulation framework, a wrapper, named Krangpower, was developed. Krangpower is released as Open Source software under the MIT license and is thus freely accessible at [https://github.com/supsi-dacd-isaac/krangpower](https://github.com/supsi-dacd-isaac/krangpower).

Krangpower allows accessing the different functionalities of OpenDSS within the Python simulation framework, by providing modern interfaces, such as structured information retrieval, dynamic querying, graphing, custom function evaluation during the step-by-step solution of the circuit, I/O based on JSON files, and others, to provide a generic and structured foundation and avoid the continuous need for scripts custom-tailored to the particular simulation. Krangpower gives the possibility to easily create agents that algorithmically decide their power absorption and injection with the option to use grid “measurements” (previous-step simulation results) to take their decision. After an essential, boilerplate-free definition of the smart agent behavior, the execution of the smart agent scripts is managed autonomously, and the results requested are automatically computed, extracted, and recorded at each step
as return values of the simulation. All quantities are provided complete with a unit measure (using the pint package). Furthermore, the user is able to load the base circuit from a structured JSON file, modify it as needed in the script and save/load it in complete packages, including smart entities and load profiles. Advanced analysis modes are readily available through the extraction of the circuit graph, filled with references to the circuit components, and with the subpackage graph view. The complete documentation of Krangpower can be found at the following link >> https://krangpower.readthedocs.io/en/master/.

Figure 1 provides a practical example of the kind of analysis that can be performed using Krangpower when it is integrated into the NEMoGrid simulation framework. A simulation is performed on the IEEE European Low Voltage Test Feeder [02]. In this example, the simulated loads and generators connected to the example grid are managed by test algorithms developed during the project.

For the Swiss pilot project, the exact grid topology of the test site was replicated and simulated in Krangpower.

Figure 1: Example of load flow simulation on the IEEE European Low voltage Test Feeder. Hexagon size represents the voltage at the end nodes, line thickness represents current, active power at the end nodes is color-coded.
**Probabilistic Power Flow**

The load and generation prediction within the test sites is subject to uncertainties due to unforeseen weather development or unusual user behavior. To be able to estimate the effects of this uncertainty on the grid voltage, various methods to propagate the uncertainties have been implemented.

The first method is a state estimation based on the weighted least squares (WLS) algorithm [03]. The second method is based on the error propagation law and allows a faster calculation of the results. The error propagation takes about 25% of the time compared to the WLS algorithm due to less complex matrix inversions. Furthermore, error correction has been implemented to decrease the estimation error due to linearization errors. Figure 2 shows the estimation errors for voltage magnitude and angle of the different implementations.

![Figure 2](image)

*Figure 2: Results of the different methods implemented within the probabilistic loadflow tool. On the left error in standard deviation for the mean voltage of all buses is shown. The right side shows the estimation error in the standard deviation error of the voltage angle.*
REFERENCES

[02] https://site.ieee.org/pes-testfeeders/resources/