STORY

STORY highlight Nr.1

STORYs Large Scale Modelling and Simulations Approach

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1 Introduction

The more diverse the power system is becoming in terms of new technologies and actors, the more important is an accurate and detailed understanding of its operation. For this purpose, STORY has developed a platform for reliable network simulations presented here.

First, the use of energy storage devices impacts the amount of energy generated by variable Renewable Energy Sources (RES) that the power system can absorb. STORY focusses on batteries, compressed air energy storage and thermal storage of different size. With their ability to adapt quickly their power settings these energy storage technologies can offer flexibility to the system. They are able to provide downward and upward power adjustments to deal with temporarily imbalances between generation and demand. This ability can be offered as a service in short term electricity markets (day-ahead, intra-day, and real-time), reaping the arbitrage-based rewards.

Second, the integration of storage devices impacts both transmission and distribution level of the power system. While the storage operation can directly influence the power quality and operation of the distribution grid by changing the voltage profiles and the loading in the grid feeders, the impact on the transmission system is more indirect. However, a coordinated operation of the aggregated small, distributed storage devices, in particular batteries, can change the transmission-level load behaviour. Such operation may also allow the participation of these devices in the capacity market to provide transmission-level grid services.

In this part of STORY, we focus on batteries as the most common form of electricity storage technology. To determine the operational and economic impact of electrical storage units on reliability and power quality of medium voltage (MV) and low voltage (LV) distribution networks, we need to consider several aspects important for storage valorisation. By looking into the role of storage in setting the investment- and operational conditions in distribution- and to some extent in transmission network, we will gain an insight into the economic impact and viability of storage implementation. Techno-economic comparison of deferred traditional grid-oriented investments in distribution network and storage costs using the STORY simulation platform will be the focus of our investigation within this part of the project.

2 Network model

The process to analyze the value of large-scale integration of small-scale battery storage solutions in the power system is shown in Figure 1. We use the STORY simulation platform to obtain technical results using power flow analysis. Based on these results, value analysis using key performance indicators is performed.

The network model used in the STORY simulation platform focuses on the assessment of storage impacts in MV and LV distribution networks. It was designed to enable simulation of advanced battery storage model and the associated smart control algorithms, which are being developed in parallel ongoing tasks, and to facilitate the stochastic evaluation of the value provided by the various combinations of flexible energy generation and consumption. It contains separate models of storage, photovoltaic (PV) energy systems, electric vehicles (EV) and loads. The network parameters were determined initially together with the scenarios of network development and storage implementation earlier in the STORY project. Based on those parameters, development scenarios were applied to the LV and MV distribution grid model targeting markets for electricity and ancillary services. The models are built using a combination of Matlab and OpenDSS software environments. Using the results of the technical simulations, Key Performance Indicators (KPI) have been calculated, with an economic assessment following later in the project.

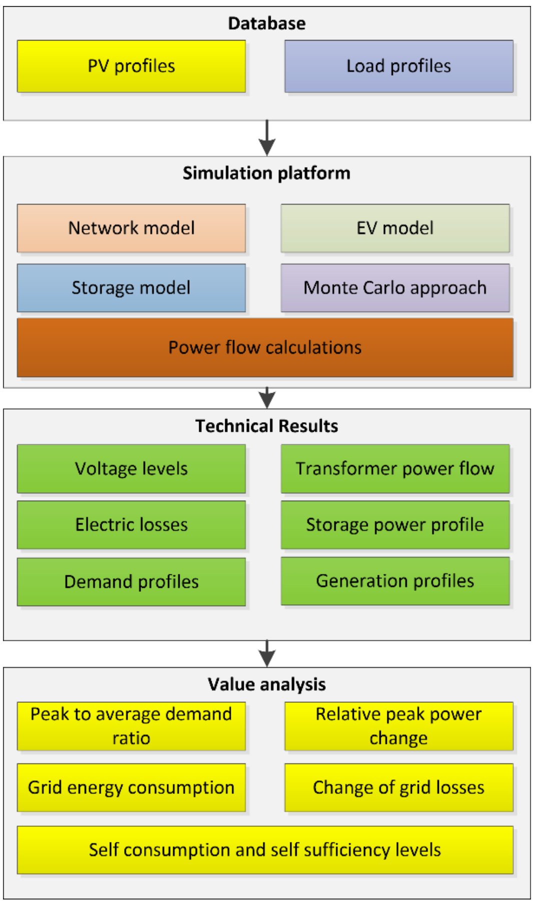

Figure 1: Simulation and analysis process

3 Input data

Since the electricity demand and PV generation are both highly variable parameters, we selected a combination of deterministic calculations of power flow supported with stochastic modelling of demand and PV generation using the Monte Carlo method. This way, loads and PV generation calculation are based on the past measured data from a database and on the predicted maximum (peak) load. This method provides us with average values with the associated probabilities (expressed as variance) rather than unique values of electrical parameters (e.g. voltages, power flows…) in the examined network.

The inputs to the simulations include:

- Load profiles: annual load profiles (15-minute data) of household consumers (e.g. 1000 households).
- Generation profiles: annual generation profiles (15-minute data) of distributed generation (DG).
- Control algorithms: including DG, storage, and on-load tap changing (OLTC) transformer.

We cover the seasonal effects by simulations of all four seasons, and the geographical impact is covered by region-specific (South, Central and Northern EU region) demand profiles that differ for rural and urban aspect.

4 Example for an application case

As one of our demo cases in STORY we plan to implement a 250 kWh community battery storage unit in a grid section in the village of Suha in Slovenia which has 70 households. The synthetic network models and demo models of the Slovenian DSO Elektro Gorenejska shown in Figure 2 present the core grid structure for the simulation process.

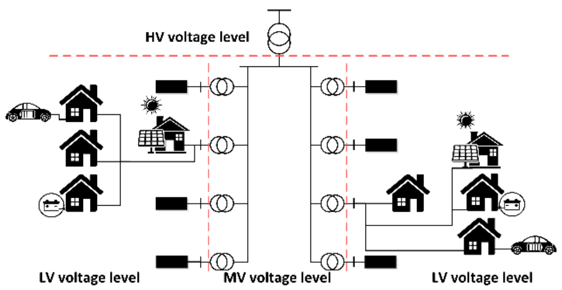

Figure 2: Network structure and development parameters

To simulate the future conditions, we have applied network development parameters to the existing network structure. Four variable parameters defined seven scenarios, which were simulated for all four seasons, with the central European grid data as the first step. For the demo models, available measurements were used as input.

Our network development scenarios defined the **peak demand level** in the LV networks, the **installed power of RES** in the network, and the installed capacities of **EV** and **storage**. Table 1, presents a brief overview of the parameters.

Table 1: Scenario parameters definition

Scenario	Peak demand value	RES installed power	EV installed capacity	Storage installed power
1	55 %	40%	5%	0%
2	55 %	40%	5%	15%
3	55 %	40%	5%	30%
4	55 %	110%	40%	0%
5	55 %	110%	40%	40%
6	55 %	110%	40%	80%
7	55 %	110%	40%	*Central unit*

All values are expressed in percentages of the nominal power of the MV/LV transformer, supplying individual sections of the network.

Demand peak power value calibrates the aggregated demand profiles for a subsection of the network. Once the aggregated demand profile is known, the power demand in each instance is distributed among the loads in the network. **RES Installed Power** in each section of the network comprises small, dispersed, 3-phase PV generation units randomly spread throughout the network until installed capacity is met. **Electric vehicles** in the network are defined with the aggregated amount of nominal power of the units. Charging stations of the EV are randomly placed in the network, and each unit is 3-phase connected with a predefined nominal power. Charging process also assumes random charging intervals of the EV, with an emphasis on the overnight charging following the assumed two-tariff pricing scheme. Typical 3-phase **battery units** 15 kW rated power are randomly allocated to households in the network. In Scenario 7, a 800 kW network-level battery unit with 660 kWh capacity is installed at every MV/LV transformer in the distribution grid.

5 Analysis and results

The integration of battery storage devices has a considerable impact on the power system on different levels. In STORY, we have devised a method to assess the impact of large-scale implementation of distributed storage in the power system. We compare the results of scenarios assuming different number of installed household storage units, PV units and centralized storage units in the network.

Table 2 presents the selected results of the technical KPIs, namely the **network losses** and the **peak loading levels**. The spring interval was chosen as it represents the season with the highest PV production rate, since during that period the rising temperatures don't affect adversely the PV production as in summer. In the evening, demand is still high due to low temperatures and high overall energy consumption. Network losses had similar trends throughout the whole system.

In Table 2 and Figure 3, we see impact of different scenario parameters on the network losses. Scenarios 1 to 3 show that low PV penetration in combination with storage installation reduces losses by a few percent of the original values of Scenario 1. Scenarios 1 and 4 show the direct impact of the increased PV production, and in Scenarios 4 to 6 we see how storage can reduce losses in the network up to 10 % in the higher scenarios. Scenario 7 represents installation of a central storage system unit as opposed to the household installations in previous scenarios.

Table 2: Network losses comparison, spring in kWh/day

Case	Grid level	Transformers	Lines	LV Urban network	LV Rural network
1	5510,9	3269,2	2241,7	53,1	37,0
2	5464,5	3262,6	2201,9	52,9	36,7
3	5450,8	3261,5	2189,3	52,7	36,6

4	6562,2	3491,7	3070,5	71,6	39,6
5	6218,4	3396,9	2821,5	65,1	38,8
6	5882,8	3316,2	2566,5	61,3	37,6
7	6003,7	3209,1	2794,7	69,9	39,0

Due to the central location of the storage covering some 120 households in Scenario 7, a lot of power is still flowing in the network between RES sources and storage. The flow rate improvement of the network loading of transformers is shown in Table 3 and Figure 4.

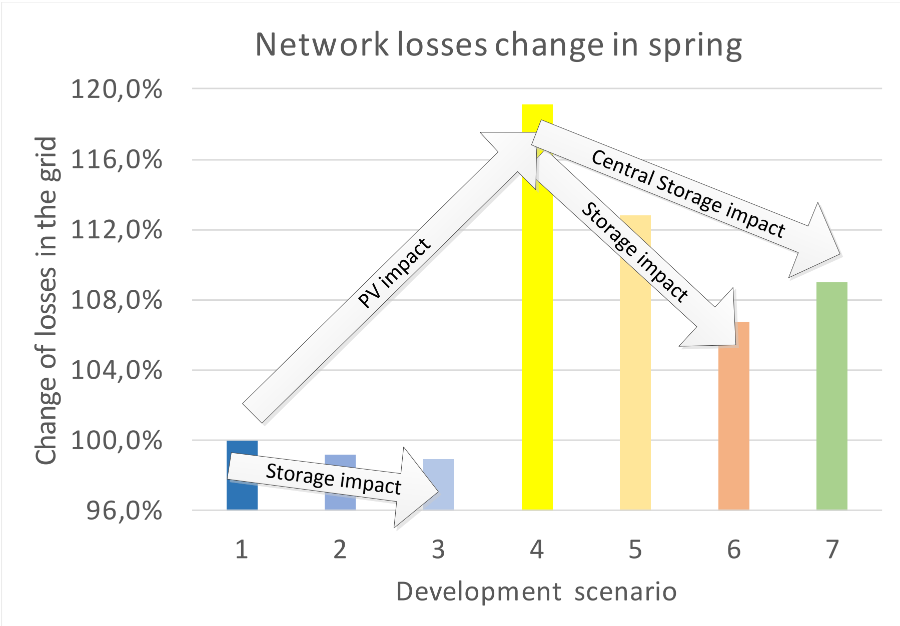

Figure 3: Losses in the network comparison

Table 3: Loading comparison in spring interval

Peak loading level of transformers			
Case	**HV/MV**	**MV/LV urban**	**MV/LV rural**
1	61,4%	59,6%	61,0%
2	60,4%	58,0%	60,1%
3	59,8%	56,4%	59,6%
4	66,0%	68,2%	65,5%
5	64,0%	63,8%	63,3%
6	61,3%	59,7%	60,5%
7	58,5%	59,5%	43,8%

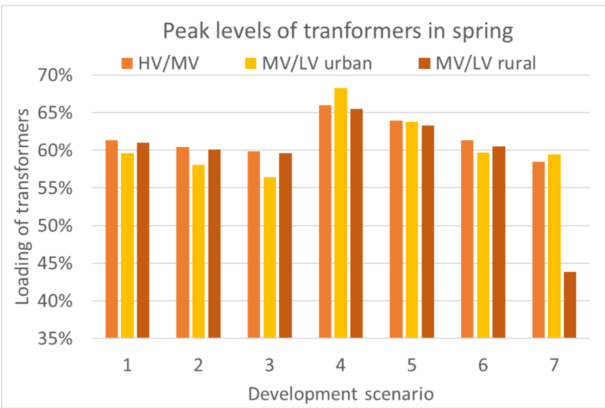

Figure 4: Peak loading levels of transformer in spring

6 Conclusions

The technical simulation results and calculated KPIs show positive impacts of storage on the network operation. The most critical season for the network is spring, due to high PV production and relatively high electricity demand. In a first set of scenarios (1-3) with low PV penetration, storage impact is observable, although its contribution to reliable operation is not actually needed, since the modelled grid is quite resilient. The following Scenario 4 represents the future network, where PV penetration is increased, affecting the reliability of the network operation. With the storage implementation in Scenarios 4-7 we investigated how storage helps to mitigate the reliability problems, caused by the higher RES production. Scenario 7 finally provides a comparison of the network-wide solution compared to the household solutions in the previous scenarios. The results of the central storage unit implementation show overall network improvement on a higher level. Due to the size of the unit, it cannot be fully utilized in rural networks with smaller demand: energy flows in the network are still increased in the central battery case compared to the household solutions, resulting in high loss rates but decreasing the overall loading of the network, specifically of the transformers. Central storage in the distribution grid can therefore serve well as a system-wide solution implemented by the DSO if penetration of distributed storage remains low or if the central storage turns out to be economically more viable.