A METHOD FOR FLEXIBLE LONG-TERM PLANNING WITH AGILE ADAPTION TO CHANGING REQUIREMENTS

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ABSTRACT

In this paper we suggest a new planning process for distribution grids considering the evolution of the supply tasks. Uncertainties are taken into account and their risks are counteracted using agile adaption measures. Both conventional grid expansion and innovative solutions are incorporated. The process is tested in a case study for a selected subgrid in the city of Zurich. Uncertainties are introduced using diverging scenarios for electromobility. The results show that agile planning processes are an option for DSOs and enable them to reduce the risk of misinvestments due to changes in forecasts.

INTRODUCTION

Grid planning nowadays has to cope with many uncertainties. Traditionally, the main drivers for distribution grid development have been load growth and additional connections to new supply areas. The further expansion of renewable generation and electric vehicles (EVs) is difficult to predict, as both are highly dependent on political and customer decisions. The progress in the field of smart home and Internet of Things (IoT) and its impact on the grid is also hard to foresee. The above developments challenge the long-established planning approaches and put investments in assets with life durations of several decades at risk.

Therefore, the future grid planning process needs to become more flexible. Investment decisions have to be assessed taking into account the uncertainties in order to minimize the risk of misinvestments. The frequency of the planning process must also be reconsidered, as changes happen faster and more dynamically than in the past decades. Smart grid technologies, like grid storage or voltage regulators, can serve as measures to buffer uncertainties and play an important role as permanent or interim solutions. This way, the grid planning becomes more agile.

PLANNING PROCESS

The planning process proposed in this work can be split in three parts. At first, the inputs are defined, then the actual model for the calculation of the measures to be taken is run and afterwards the financial impact of the different solution scenarios is assessed. Finally the decision for the actions to be taken within the examined planning horizon is made.

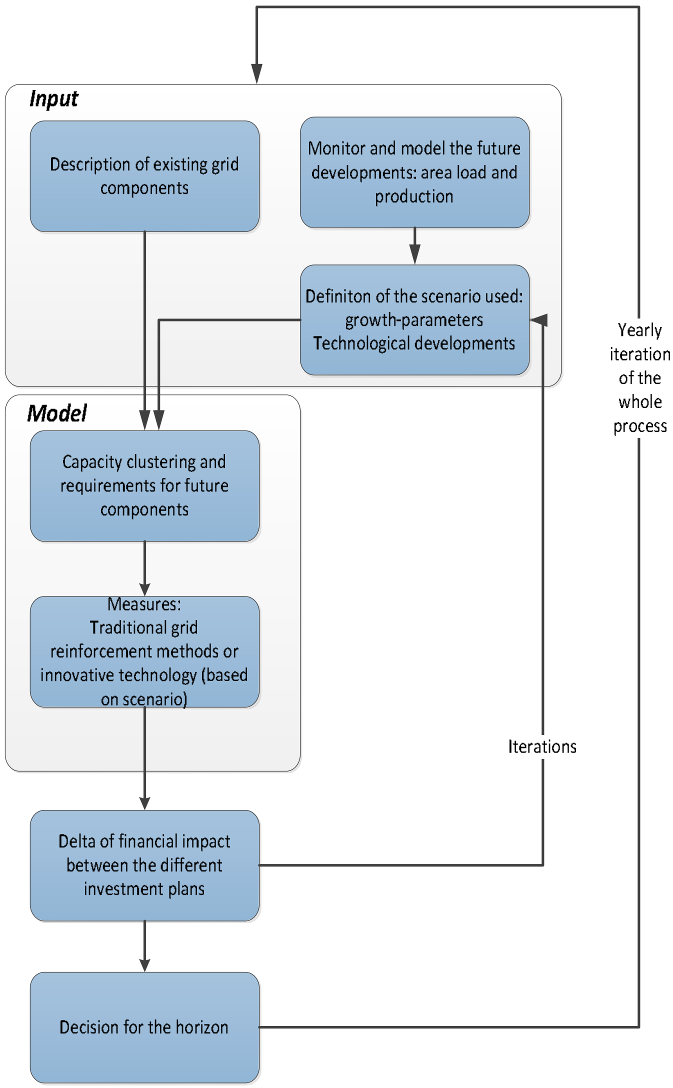

Figure 1: Steps of the proposed method

Input Factors

First, scenarios for the future supply task are defined. These include the most important factors as developments in load, production[1] and in new technologies like electromobility. These scenarios and the existing grid structure are the inputs to the model. The grid topology is implicitly introduced through a hierarchy of the grid components, starting from the LV distribution cables and going up until the connection to the substation. The grid topology is modelled by the number of grid elements and their capacity, the distribution of the maximum power on the feeders and a simultaneity factor on each hierarchy level.

The load and production development are introduced as continuous non-dimensional (p.u.) growth curves. A linear development is usually assumed for the load and an S-curve for the photovoltaic production. Through these curves, different scenarios, depending on the expectations of the DSO, can be represented. Consequently, further technological developments such as electromobility are also expressed as an S-curve and serve as an input to the model. Building up the scenarios is a complex and very important step of the process, as these forecasts significantly influence the planning results.

Model: Selection of measures

In this step, the actual model is run. It calculates the extra capacities required in the grid on each of the defined hierarchy levels as the time and the scenarios evolve. The exact methodology is described in the following chapter. Depending on the results and the technologies available to address the problems, conventional and innovative measures are included. As far as conventional measures are concerned, cable installations, replacement of existing transformers by bigger ones and building of new distribution cabinets (Cab) and transformer stations (TS) are taken into account. Innovative measures could be the deployment of batteries, voltage regulators, intelligent charging of electric vehicles, etc. The last innovative measure will be examined within the scope of the case study in this paper. The solution consists of a quantity structure of components. It is important to point out that the forecast of the inputs and outputs, i.e. capacity requirements, are yearly values, which additionally allows the planner to determine the investment point in time. The model does not give information about a specific grid component location wise as the topology is only implicitly introduced.

Calculation of the financial impact

The required measures are then financially assessed by allocating standard costing to the resulting quantity structure of the components. In this step, the different solution paths, i.e. investment plans, are compared and evaluated.

[1] Only photovoltaic production is to be expected in the city of Zurich.

Agile adaption to changing requirements

As the process is iterated every year and several scenarios for the uncertain developments are run, the measures are not only evaluated regarding their ability to solve the known challenges but also on their adaptability for a range of scenarios.

METHODOLOGY

Within the scope of the project “Future distribution grid”, ewz, the DSO of Zurich, developed a method to monitor and model the development of the main drivers and determine the future technologies and quantity structure of the grid [1]. The further development of this method is presented in this paper. The model incorporates both conventional grid expansion as well as new grid solutions and is therefore referred to as “New Technology Model”.

New Technology Model

The New Technology Model is a bottom-up model, which is based on the hierarchy of the grid components [1]. The component LV feeder as lowest observation entity is characterized by the maximal power input and output of the customers connected to the feeder. The next entities are distribution cabinets, transformer stations, MV cables up until primary substations.

The model, shown in Figure 2, is based on the following characteristics:

- Natural hierarchical structure is determined by the grid (radial network assumed).
- The components on each hierarchical level are grouped into classes. The principal criterion is the capacity limit.
- The maximal load of a grid component due to consumption or production is described by a probability distribution (gamma distribution, [2]).
- On each level (e.g. voltage level) the maximal load of a component is the aggregation of the load of the component classes on the lower level (folding of distributions).
- The number of overloaded components in a class is estimated by the portion of the distribution above the class limit (any requirement that limits the capacity of the components in that class, usually the thermal limit). This portion is naturally shifted to the next class with a higher limit.
- The future change of consumption or production is simulated through the change of a distribution parameter (for gamma distribution the rate parameter
- Distinct network-areas can be represented by different distribution parameters for their component classes (e.g. due to different growth characteristics in consumption or production), giving the opportunity to define groups of components (s. Figure 2)

Since the optimization is based on the expected values for the study period, the variance of the forecast for year k becomes smaller the closer year k approaches.

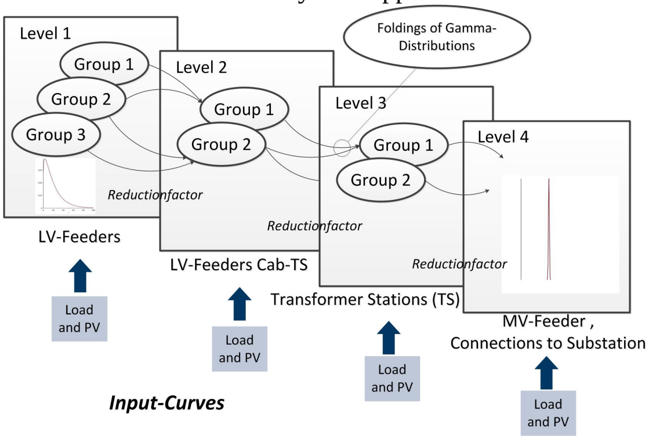

Figure 2: Hierarchy of the New Technology Model

CASE STUDY ELECTROMOBILITY

The application of this method for a case study regarding the development of electromobility in an urban district is presented here. The main focus lies on the impact of different development paths on quantity structure and costs.

Scenarios

Within the scope of the project "Future distribution grid" of ewz, a reference scenario for the development of production and consumption in the city of Zurich was formulated. The main points of this scenario are:

Factors of influence	Development until 2050
Renewables installed (PV)	High 600 MW_{eff} (80 W_p/m^2)
Decentralized storage	30% of the PV-Power (180 MW)
Load development (wo. electromobility)	Maximum load rises due to increased concentration in the city (800 MW)
Electromobility	90% penetration 25% of the cars are being used daily on average 50-60 km/d 25 kWh/100 km Charging stations with 11 or 22 kW
Load management	Potential 70 MW (10% of maximum load, e.g. heating, cooling), electromobility can also be controlled, only 10% of the cars can charge with the maximum power, 90% can be shifted over 10h (Charging overnight)

We introduce four scenarios for the development in the electromobility sector. They all conclude to the same value for 2050, the value of the reference scenario. The difference lies in the path that is followed to reach this value. The four scenarios examined are disruptive, fast, anticipated and slow and are presented in the following graph until 2050.

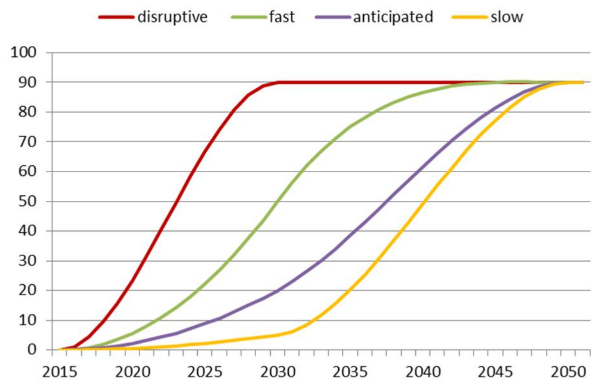

Figure 3: Electromobility scenarios for the city of Zurich

Selected subgrid

The grid selected for this study is an urban grid in the city of Zurich with several types of customers (households, services, industry, etc.). In total, the substation supplies around 35'000 customers with a maximal load of 65MW through a medium and low voltage grid. Today, there are 37 photovoltaic units installed in this area with around 1600 kW_p installed capacity. The feeders and transformer station areas are separated in three groups, depending on their expected electromobility and photovoltaic development. Electromobility potential was estimated taking into account the potential for living space and car parks of residential buildings, as the main share of electric charging is expected there. For this case study, the 90% penetration percentage at 2050 applies to the maximal potential for each group. One comprehensive scenario for the future development of load and photovoltaic production is analyzed in combination with electromobility developments, according to Figure 3.

Results

The results of the simulations for the above grid and scenarios are presented in the following graphs, representing yearly costs. These curves are derived linearly from the changes in quantity structure. Therefore, only costs are displayed.

In Figure 4 and Figure 5 the yearly costs for the necessary grid expansion due to both load growth and electromobility growth are presented. Replacement due to age is not included in this analysis. Past studies have shown that there are synergies if replacement due to age is taken into account. In this case, the replacement plan has to be defined in a way that the components that are replaced due to age will not be replaced again shortly

afterwards due to overloading. As the approach used in this paper is not based on individual components, possible synergies can only be roughly estimated on the basis of statistical age distribution. For the first figure, an intelligent charging system for the EVs in car parks is assumed to avoid simultaneous charging in order to shave peaks. The costs are represented p.u. in relation to average yearly investment costs for a substation supply area.
The necessary grid expansion is determined by the increase of load and electromobility and not of PV production for the grid under consideration. Consequently in this case for maximum load flow zero PV production is assumed.

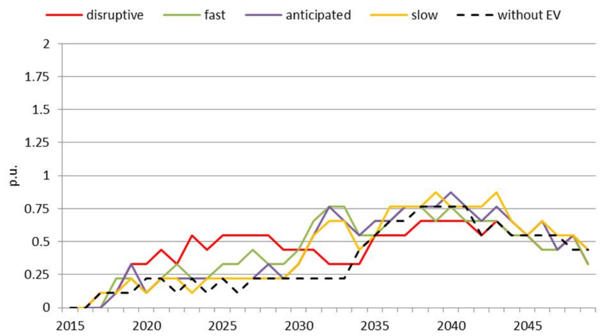

Figure 4: Yearly grid expansion costs due to load and electromobility growth assuming intelligent charging

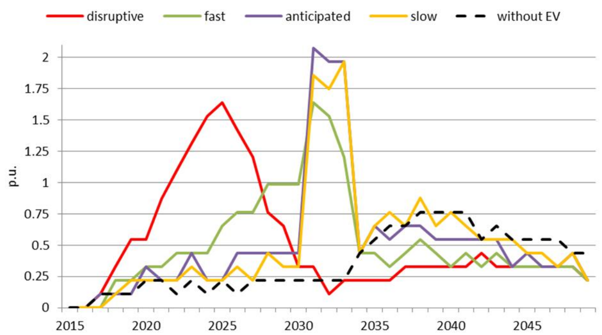

Figure 5: Yearly grid expansion costs due to load and electromobility growth assuming free EV charging

The curves in both figures differ significantly for the time period before 2035. That shows that even a small penetration of electric vehicles (e.g. 25% for the slow scenario in 2035) causes significant grid expansion costs. After 2035, most necessary conventional grid expansion measures are already taken. Therefore, there is only minimal difference to the scenario without EVs.

Subsequently, the effect of the electromobility is analyzed separately by assuming zero load growth. The results for the four electromobility scenarios are presented in the following graphs; Figure 6 assuming intelligent charging of EV and Figure 7 assuming free charging of EV.

In both cases (with and without intelligent charging), investments are already necessary in the near future, until 2030 for the disruptive scenario. The existing grid is clearly not equipped to accommodate that many electric vehicles so soon. Therefore, extensive grid expansion will be necessary. For the other three scenarios, the results are similar and the first extensive investments are needed after 2030. Most of these investment costs are caused by the need to build new transformer stations.

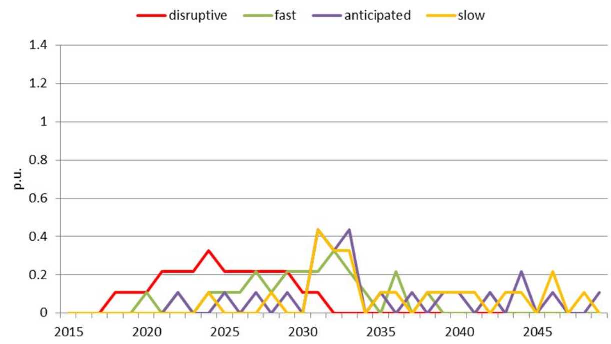

Figure 6: Yearly grid expansion costs due to electromobility assuming intelligent charging

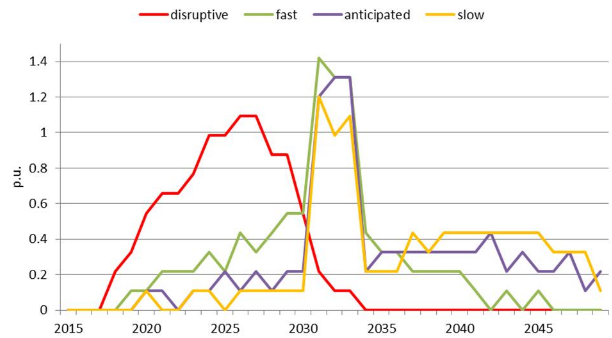

Figure 7: Yearly grid expansion costs due to electromobility assuming free EV charging

The costs without intelligent management are much higher in all scenarios. This finding offers a valuable input for future projects. Intelligent management helps customers (mainly operators of parking lots) avoid overloading of their cables and high electricity bills in case of peak penalization. At the same time, it allows the DSO to avoid costly grid expansion measures.

After the analysis by the model, the yearly investment budget over the planning period (e.g. 5-20 years) is specified. The investment plan is deduced from the costs calculated by the model. In this case the costs for the combination of conventional grid expansion and intelligent charging (Figure 6) are lower than for conventional grid expansion alone (Figure 7). As the first agile measure intelligent charging in car parks would be applied and at points of the grid, where bottlenecks occur, conventional grid expansion.

The goal of this study was to test the robustness of investments in case of unexpected changes in the developments of the grid needs. Based on the above graphs, it can be deduced that varying developments in electromobility cause significantly different investment costs. If we consider the fact that electromobility is only one of the parameters that influence grid expansion measures, imply the importance of agile investment planning.

The results for the developments in the electromobility sector have shown that a horizon of 5 years for the short-term planning with yearly iteration seems reasonable. The yearly iteration of the planning method, as defined in Figure 1, helps foresee unexpected changes in the development of the parameters.

CONCLUSIONS AND OUTLOOK

Considering the developments that are supposed to redefine the electrical grids of the future, new approaches have to be taken into account in planning. Conventional and innovative measures have different characteristics:

- The planning periods for new technologies are shorter than for conventional grid expansion.
- New technologies do not necessarily need to be used as permanent solutions; they can also be cost-effective intermediate solutions until conventional grid expansion becomes necessary at the end of a component's lifetime.

It is clear from the case study analyzed in this paper, that a yearly iteration of the process is important, as the costs change significantly for different scenarios. If the development path taken as basis for an investment plan significantly changes, misinvestments could occur. Through agile planning, such misinvestments can be prevented. Summarizing the work, the conclusion can be drawn, that agile planning methods with shorter planning intervals result in reduction of investment risks but at the same time increase the complexity of the planning.

As future step, the integration of optimization algorithms into the New Technology Model is possible. The model can be expanded to include a 5 or 10 yearlong forecast of the necessary grid expansion. If that is available, the replacement due to age can be better optimized to avoid double investments. Furthermore, other innovative technologies e.g. batteries, line voltage regulators could be incorporated in the analysis.

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[2] N. Balakrishnan, Samuel Kotz, Norman L. Johnson, 1994, *Continuous Univariate Distributions, Volume 1*, Wiley John & Sons