

Concept for the use of automated network planning in the distribution network level with coordination of various grid extension measures

Hermann Kraus^{1,*}, Oliver Brückl¹

¹OTH Regensburg, FENES, Seybothstraße 2, 93053 Regensburg, Bavaria, Germany,

*hermann.kraus@oth-regensburg.de

Abstract

In this thesis, a concept for the automated use of network planning processes, which is part of the decision support system developed in the framework of the EU project CrossEnergy, is presented. This publication focuses on the automatic processing of input data and subsequent network modeling as well as the coordination of network extension measures for the systematic solution of static voltage and current problems. Different variants are calculated in order to be able to compare the design technologies.

Keywords – Automated grid planning, grid extension measures, grid planning tool, power system, electrical supply

1 Motivation and purpose

The distribution system operators (DSOs) face new challenges as a result of the changing energy transition. Bidirectional load flows, the feed-in of decentralized generation plants and new consumers such as e-mobility play an important role. For this purpose, in this work an overview for the implemented grid-planning tool and for developed routines regarding to automated calculation in load flow calculation program PowerFactory is presented. Overall, the infrastructure to include the grid-planning tool into a decision support tool is also shown. The automation of network planning steps is intended to help the DSOs to recognize the possibilities of implementing a network extension in the case of current or voltage violations. They should be able to evaluate with the help of technological and economic indicators, which extension variant is best for their network [1].

2 Automation of grid planning processes

Automation of the network planning steps means that a corresponding algorithm must be able to deal with all network cases. For this purpose, a generally valid method for solving current and voltage problems plays an important role, since it ensures that the implemented scripts provide a correct result for any network topology and problem structure. In order to find the best solution globally, it is possible to perform probabilistic calculations, but this requires a lot of computing power and much of the computational work could be saved by an exclusion procedure. The use of heuristics aims at a methodological minimization of the solution space, but often reaches its limits if a global solution is to be found. Therefore, for the network planning tool presented in this work a combination of heuristics and mathematical optimization approaches is chosen.

3 Program architecture

The OTH Regensburg, the University of West Bohemia (UWB) and the TH Deggendorf (THD) are involved in the EU project CrossEnergy (**Figure 1**), in which a decision support system (DSS) is developed, which includes an automated network planning tool. In this case, the THD is responsible for energy and forecasting data, the OTH for network planning in accordance with a predefined scenario for load and generation development, and the UWB for a grid analysis for state and potential assessment. All three partners access a central data platform for import and export. A network operator should also be able to store his data on this platform, which then is used by the OTH to generate a corresponding network model for the load flow calculation program PowerFactory. The calculations in the complete system architecture are carried out automatically. Associated with this is the development of corresponding concepts and algorithms, whereby the following sections focus on the methods of the OTH [1].

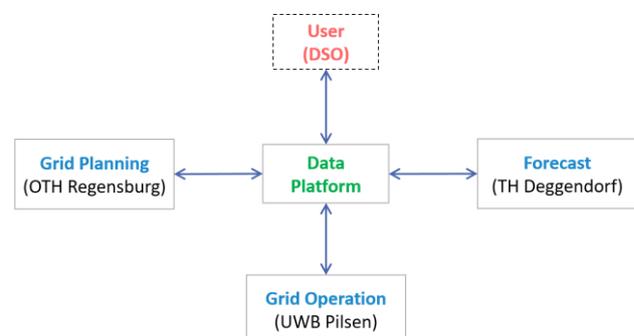


Figure 1 System architecture of the DSS

3.1 Data exchange with the central data platform

In addition to the network topology, detailed information about the equipment as well as the network participants is necessary for well-founded network planning. The OTH obtains this via the central data platform, which has been filled in by other actors (users, THD, UWB). Likewise, this interface must also be used to exchange information about the defined load and generation development as well as the time series for the network model.

The exchange has been developed using the json format. The OTH uses a developed Python script to communicate with the data platform and to extract automatically the information from the corresponding json files. The decisive factor here is, that the previously defined structure of the individual categories (line, transformer, load, etc.) for the json file is adhered to, which represents the necessary data communication between the OTH and the data platform.

3.2 Processing input data

For handling the input data automatically, a routine in Python was developed. The program language Python is also the interface of PowerFactory for data exchange (input, output) to other instances.

First, the incoming data is checked for plausibility. For this purpose, the data is categorized into necessary and optional input data. The necessary data represents information, which no default values can be defined by the OTH. These include, among other things, the GPS coordinates of the network elements. In the case of the optional data, empirical values are stored as default values if no specific information is given via the json file. Within the concept of the default values, the user has the option to set many optional values with his own data (expert level), but can also import only the necessary data and use the default values for the calculations.

In the next step, the input data is used to generate automatically a corresponding network model in the power flow calculation program PowerFactory with the developed Python script. After the nodes, transformers and cables have been created, all remaining network participants are connected. Each network element has several properties. Thus, e.g. in addition to the GPS coordinates and the voltage level, the low voltage (LV) nodes have various voltage limits stored: firstly the legal value with $\pm 10\%$ V_n (nominal voltage) and secondly the plan values specified by the grid operator (for example +2% or -5% from the LV busbar of the distribution transformer), as in **Figure 2** depicted. In case of the nodes, there is a third value, which is considered by the algorithm, the target values. They are used, if a measure is solving a voltage or current problem. Because, if a measure would solve a problem without this value, it would set the voltage back to the legal limit or plan value. But with the target value, the measure will solve the problem until some voltage value for some buffer reason regarding to future load or generation development. In **Figure 2** it is a buffer

of 2 % to the legal/plan value. In comparison to the plan values and legal limits, the tool will not identify a voltage or current problem, if the target value is overreached. It is only used, if the measures begins to solve a problem. These three values can be stored individually for each node or for the entire voltage level.

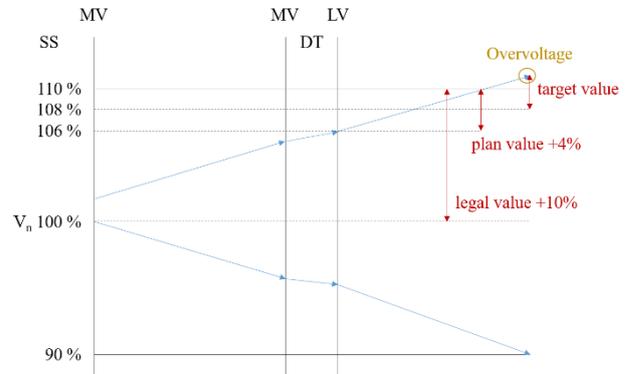


Figure 2 Voltage band from substation (SS) over the distribution transformer (DT) with legal value, plan value and target value

After mapping the network topology in PowerFactory, appropriate time series are assigned for the loads and generators. In general, it is also possible to include time series for storages or network equipment. In addition, the network elements receive, besides to their original ID, an additional name for internal purposes to increase the efficiency of further algorithms. Focus here was to simplify the algorithms of later used grid extension measures.

Figure 3 presents the used name concept, which is explained looking at the first power line: the first number (“7”) gives information about the voltage level. In this case, it is low voltage. “001” just behind the “7” indicates the grid number. This is relevant, if in the network model are more than one low voltage grid. With the second part (here also “001”) is documented the busbar. The third part (again “001”) gives information about the considered string. Strings are in this case lines, which are going out from the busbar, and includes all subsequent elements. The fourth part indicates, in which sector of the string the element is located. Here are the sectors defined by main nodes, that means the busbars, the nodes with more than 2 lines connected (node after the viewed line) and the last node of a string/substring (two grid ends on the right). The last part of the name includes with the number “06” the type of the named element (in this case a line) and the number of this type “001” in the section.

This function for naming the grid participants with an additional ID was developed in the internal program language dpl of PowerFactory.

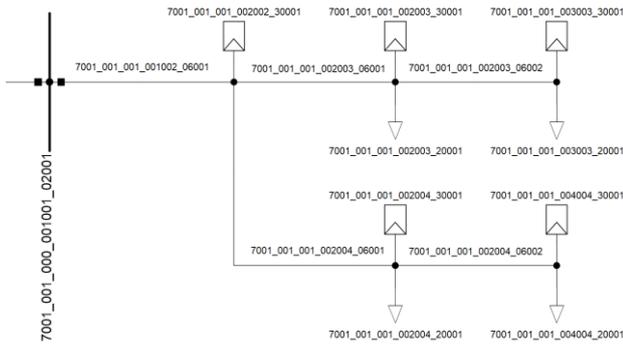


Figure 3 Name concept (ID-number of each network participant) for generated grid model

3.3 Output data

After the calculation of all extension variants (for example, cabling or reactive power control) a planned network per extension variant is transferred as output to the data platform in json format. The documentation of the planning process is also transferred for transparency and understanding reasons. The documentation includes, among other things, the progress of the extension variant, i.e. at which time and location a technology was used to eliminate a network problem as well as its corresponding costs. The output process is also implemented into a Python routine.

4 Automated grid planning tool

With the construction of the complete network model starts the calculation of the scenario. The scenario includes the load and generation development in form of change of the installed power per year ($\Delta P/a$) or in a direct power change (ΔP). It is also possible to define the change separately for one load or generation unit, or for some class of them (e.g. households). The scenario can also include new load or generators units, which has then to be connected to the grid model.

First, the current state of the network is checked for plausibility by means of a load flow calculation using a standard feature of PowerFactory. If no problems occur, the further load and generation development is entered into the existing network topology. If problems occur in the original network structure, corresponding network extension measures, which are developed in dpl for solving problems automatically, are already used here. For emerging network participants where the user did not specify the node, the developed algorithm computes the nearest node, regardless of whether this results in a voltage or current problem. The resulting network problems are then solved by measures of the tool. In order to optimize the connection of new participants, an algorithm is currently being developed that determines the best connection point both technically and economically. For example, the costs associated with connecting to the shortest distance node and the resulting measures to solve the voltage and current problems can be compared to the

costs associated with connecting the nearest node from which no voltage or current problems follow.

The developed program uses a feature of PowerFactory that can be used to determine load flow calculations for a period of time (for example hourly values for a full year), called quasi-dynamic simulation. If problems occur in the network topology with the existing time series, then first of all the most serious problem case is dealt with, that means the time with the maximum deviation from a voltage or current limit value. In **Figure 4** is a qualitative example of a quasi-dynamic simulation depicted. In red are showed the results for the current, in blue for the voltage. The algorithm detects the worst points calculated from the quasi-dynamic simulation, which are encircled in the figure. In addition, only the times with maximum current errors are solved before the times with the largest voltage errors are treated. The reason for this is that, in experience, the likelihood of reducing or even resolving a voltage problem of the same or another time point by resolving a current problem is higher than the other way around. However, a concrete validation of this procedure with regard to the individual measures is still pending. Thus, it would also be possible to make the prioritization in the solution of occurring voltage and current limit violations depending on the grid measures used in an extension variant.

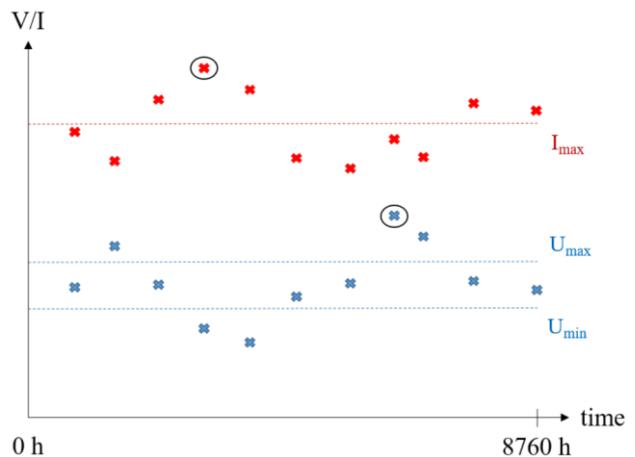


Figure 4 Results (qualitative) for a quasi-dynamic simulation (red = current, blue = voltage)

Different network extension measures are available to treat voltage or current limit violations of a point in time series (**Figure 5**). The algorithm interprets these as voltage-problem-solving measures (voltage regulated distribution transformer (VRDT), Q-control) and as voltage/current-problem-solving measures (cabling, meshing). For the coordination of the individual measures, a main program is responsible, which, among other things, controls the use of network extension methods and provides transfer parameters. This includes a problem identification and the corresponding call of the measure. Thus, e.g. to solve a current problem, the reactive power control is out of the question, or in case of a current problem on the transformer, the cabling is not used.

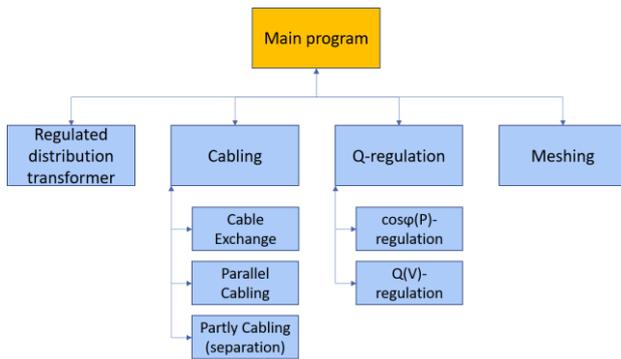


Figure 5 Coordination of the grid expansion measures [1]

For each extension variant is one primary and at least two secondary measures defined. The primary measure is the solving method, which is always used first to solve a grid problem, if possible. For example, with VRDT as primary measure, the technology tries to solve voltage problems, as far as possible. If there is a voltage limit violation, that the VRDT cannot solve, or if a current problem occurs, then the secondary measure will begin (see **Figure 6**). With regard to Figure 5, the cabling or meshing are suitable as secondary measures since they can solve voltage and current problems. Furthermore, the tool contains a script for the automatic transformer replacement with higher power class or parallel transformer, which is now always used as a secondary measure to solve current problems in transformers (not in Figure 5 contained). As an alternative, the construction of an additional station would be offered here, but this is not integrated in the current state of the project.

If a secondary measure is used to solve a current problem, then it solves only the current problem. If there is still a voltage problem after the solution of the current problem, then the primary measure is called again in order to solve the voltage problem as far as possible (see Figure 6). At this point of the algorithm, current problems are solved before voltage problems, too.

To compare different extension options, different variants for a scenario are calculated. Here, e.g. the use of the VRDT as a primary measure together with the meshing and transformer replacement as secondary measures and the VRDT together with the cabling and transformer replacement are to be considered as two variants. The variants can be further divided into sub variants, where sub variants have the same primary and secondary measures as the main variant, but the measures have other setting parameters. In example of the $\cos\phi(P)$ -regulation, a changed setting parameter could be the considered $\cos\phi$ (0.95 or 0.9). The explained extension variants are assigned for better comparison of technical and economic figures, which then the distribution system operator can use to decide which extension option is most useful for his network.

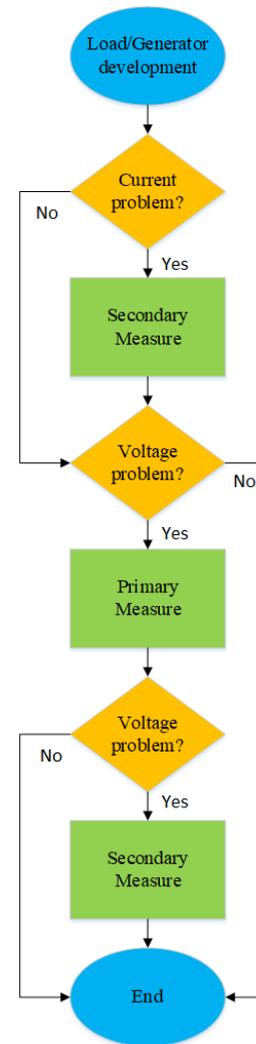


Figure 6 Flow chart for the application of primary and secondary measures

5 Summary and outlook

The automation of network planning steps offers a lot of potential as a help for network operators. Above all, an appropriate tool can give the DSO an overview of which extension measures are profitable for their network. With the combination of heuristics and mathematical approaches, the tool calculates the individual extension variants and presents them with technical and economic key figures to the user, who is then the final decision-making authority.

In the context of a higher-level decision support system, the program developed by OTH Regensburg communicates with a central data platform for the exchange of input and output data. Among other things, a data plausibility check is carried out with a defined data structure during data transmission, a network model is generated in the network calculation program PowerFactory and corresponding time series as well as properties of the grid equipment are stored.

Using a predefined scenario for load and generation development in the considered network, the existing grid extension measures are used to solve voltage and current problems. The measures are subdivided into voltage-problem-solving and current/voltage-problem-solving measures. In this case, a main program controls the activation of the corresponding measures depending on the detected problem. To calculate all possible extension options, primary and secondary measures are defined for each variant. The primary measure is used as far as possible to solve network problems. The secondary measure serves as a backup, if the primary measure cannot eliminate certain types of grid errors or technically does not have enough potential to handle the error. As a result of the tool, the user is then presented all possible extension variants for the defined scenario, whereby they are also documented with technical and economic key figures.

Automated network planning offers a large field of possibilities. First, grid planning person gets overview by calculation of the algorithm about suitable grid extension measures and can investigate deeper some other problems or effects in the grid planning procedure. Second, it saves computing time in contrast to calculate the individual steps personally in some standard load flow calculation program like PowerFactory. Individual medium or low voltage networks can be considered, or a combination of both levels can be considered simultaneously. Above all, a cross-voltage level network planning is interesting possibility in terms of technical and economic potential.

6 Literature

- [1] H. Kraus, D. Gschoßmann and O. Brückl: “Automatisierung von Netzplanungsprozessen in der Verteilnetzebene – Q(U)- und $\cos\varphi(P)$ -Blindleistungsregelung dezentraler Anlagen als spannungshaltende Netzausbaumaßnahmen“, transcript of the conference *Zukünftige Stromnetze für Erneuerbare Energien*, p. 407-420, Berlin, January 2019.