STORAGE OPTIMIZATION IN DISTRIBUTION SYSTEMS

Roger CREMERS
KEMA – The Netherlands
roger.cremers@kema.com

Gabriël BLOEMHOF
KEMA – The Netherlands
gabriel.bloemhof@kema.com

ABSTRACT

This paper addresses the development and use of a software tool called PLATOS to optimize the application of storage systems in electrical distribution networks with distributed energy resources. PLATOS finds the optimal numbers, types and locations of the storage systems. It solves the storage planning problem, while maintaining all operational constraints.

INTRODUCTION

If storage systems are to be applied in electrical distribution networks a number of typical questions may arise e.g.:

– What type of storage systems should be applied?
– What is the optimal size of the storage system?
– Where should the storage system be located?
– What are the technical and econmical benefits of applying the storage system?

In principle such questions can be answered by evaluating separately each individual storage application alternative. In practice however the number of possible storage application alternatives for a given power system can be very large. This number depends on the number of network nodes and the number of storage systems to be installed (figure 1).

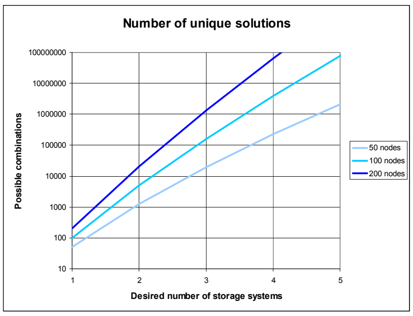

Figure 1: Number of individual solutions

The evaluation of all alternatives will therefore be very time consuming. To decrease that time, artificial evolution techniques can be used.

PLATOS is based on a well known artificial evolution technique: genetic algorithms. Instead of evaluating all possible storage alternatives, the tool generates storage alternatives itself. The generation of a new set of alternatives is based on the outcome of the evaluation of previous sets. This will result in an optimal storage alternative for a given power system and given optimization objectives and constraints.

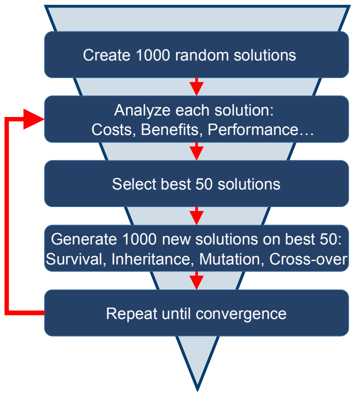

Figure 2: Principle of genetic algorithm

GROWDERS PROJECT

PLATOS has been developed within the European GROWDERS project. This project aims to demonstrate the technical and economical maturity of transportable and flexible grid connected storage systems. It includes the development and testing of storage systems, as well as the development of an assessment tool to determine the optimal location, size and type of storage systems to be used.

The GROWDERS project is funded by the European Commission. Project partners represent the entire electricity value chain and include KEMA, Liander, Iberdrola, MVV, EAC, SAFT, EXENDIS, CEA-INES and IPE. The project team includes representatives from utilities, manufacturers and consultancy firms (see [1] and [2] for more details).

FUNCTIONALITY OF PLATOS

PLATOS is a versatile and flexible tool for network planners. It can be used for all kinds of power systems and storage systems. Furthermore the optimization objectives, both technical and economical, can be defined by the user. If for instance the main objective of applying storage systems is the improvement of voltage profiles, PLATOS will find storage alternatives that have a good performance with regard to this aspect taking into account all technical and economical constraints. Other applications are preventing overloads, mitigation of voltage dips and trading.

Functional modules

PLATOS consists of a number of modules (Figure 3):

- Solution generator
- Alleviation algorithms
- Trading algorithm
- Input data processing
- Output data processing
- Alternative solutions
- Solution assessment

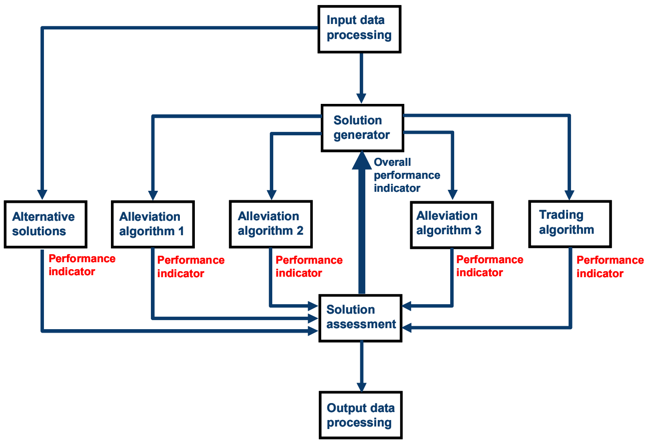

Figure 3: Functional modules of PLATOS

Solution Generator

The Solution Generator forms the core of PLATOS. Its function is to generate large numbers of unique storage solutions to achieve user defined objectives and to alleviate the technical constraints of the electrical grid. Each solution represents a specific combination of storage locations, storage sizes and storage types. The optimisation of the location, types and sizes of storage devices in a power system is essentially a combinatorial problem that can have many different solutions. Such a problem can hardly be solved not even by means of brute computational power, thus PLATOS follows a more efficient approach by using genetic algorithms. In principle the tool generates a number of random storage solutions, which are then analysed and evaluated. The best solutions are selected and then used as the basis to create even better solutions. The process is repeated until the optimum storage solutions are found.

Alleviation and Trading Algorithms

Storage systems are typically applied in distribution grids to alleviate technical problems, especially where DER (Distributed Energy Resources) are concerned. The alleviation algorithms in PLATOS assess the ability of the storage solutions proposed by the Solution Generator to alleviate each of the different technical constraints that exist for the particular distribution grid. For this purpose PLATOS uses an embedded commercial loadflow program. The result of each assessment is quantified as a performance indicator.

Besides the alleviation of technical constraints storage systems can also be utilised for energy trading purposes. The trading algorithm assesses the cost and benefits of using the proposed storage system for trading activities. The result of this assessment yields the trading performance indicator.

Solution Assessment

A solution assessment is performed for each storage solution proposed by the Solution Generator. This is done by calculating the individual performance indicators for each alleviation algorithm as well as the trading algorithm, and then combining the result in an overall performance indicator.

The performance indicator for each algorithm is calculated as the Net Present Value of the economic benefit (i.e. benefits minus costs) provided by the particular storage solution. Costs include both fixed and variable costs. Fixed costs relate to the initial capital investment of the storage system, while the variable costs relate to the number of charging and discharging cycles, energy losses, life time reduction of the storage systems etc. Financial benefits include investment deferral options as well as investment avoidance of solutions that would have been otherwise required to alleviate the network constraints.

The solution with the highest overall performance indicator is considered to be the optimal storage solution and the one that is recommended for the distribution grid. Besides the performance indicator the pay back time of each individual storage solution is also calculated.

Assessment of alternative solutions

PLATOS not only assesses storage based solutions to network problems but also classical non storage based solutions like:

- Other than default tap changer settings
- Installation of capacitor bank
- Installation of extra power connections (cable or line)

The assessment of the non storage based solutions also results in a performance indicator and a payback time. This makes it possible for the user to compare storage based solutions with non storage based solutions.

Educated guesses

PLATOS allows the user to enter so called educated guesses. Those are individual storage based solutions that the user has designed in an earlier stage and that might have a good performance with regard to the alleviation of constraints in the power system. This allows inclusion of engineering judgment based solutions, proposals from manufacturers or solutions according to company design handbooks. By entering the educated guesses these solutions are assessed in a similar way as the solutions generated by PLATOS itself and thus their performance can be compared.

INPUT OF THE TOOL

Before running PLATOS, the user has to define the solution space in which the optimal storage solution should be found. Typical input data includes:

- The network topology
- Power system component data
- The number of storage devices to be installed
- The specifications of available storage devices (e.g. size, charge/discharge rate etc.)
- Typical load and generation patterns
- Parameters to be used for the solution assessment e.g. equipment costs, cycle costs etcetera
- The assessment period
- Any restrictions with regard to the location of the storage devices

Time patterns

PLATOS allows the user to enter time patterns. These patterns can be used to model the time dependent behaviour of the individual components in the power system e.g. loads, photovoltaic systems and micoCHP. The time patterns are used in time sweeps to check all system constraints and to determine the optimal time dependent behaviour of each storage system.

OUTPUT OF THE TOOL (RESULTS)

The results of the calculations performed by PLATOS are presented in tabular form as well as graphically. The generated tables provide the user with all relevant details of the individual storage solutions. If the user is interested in the impact of storage systems on specific power system components, the tool can provide relevant details about selected components.

The calculation results are also shown in the single line diagram of the power system under study. Both diagrams showing the problems in the network and diagrams showing the storage based solutions are generated automatically.

By the use of symbols and colors the progress of the optimization process can be monitored by the user. All relevant diagrams are automatically stored for further analysis later on.

The figure below shows some of the symbols used to indicate the type and size of storage devices and the quality of individual storage based solutions.

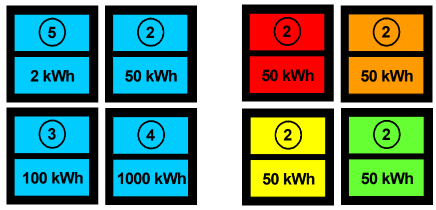

Figure 4: Symbols used in PLATOS

Blue symbols are used to show solutions that are already generated but not yet assessed. After the assessment the performance of the individual solution is shown by means of the colors red, orange, yellow and green. It is up to the user to relate the individual colors to specific performance levels.

The figures below show some examples of the way individual solutions are presented in a single line diagram.Figure 5 shows the proposed storage based solution. In this case the solution generated by the solution generator consists of 2 storage systems of different type and size located in two different streets.

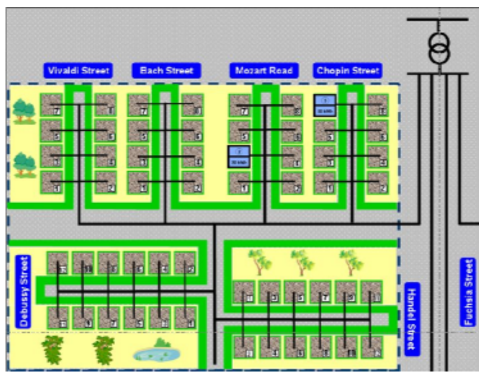

Figure 5: Proposed storage based solution

Figure 6 shows the outcome of the evaluation of this individual solution by PLATOS. This particular solutions appears to have a moderate performance (indicated by the color yellow).

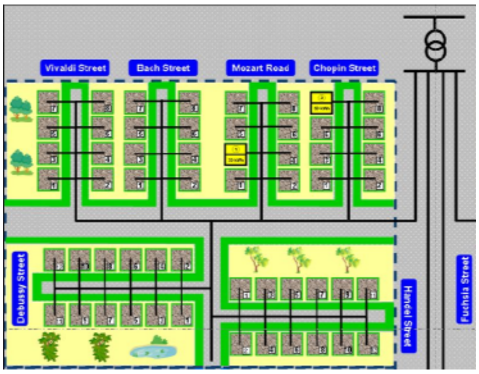

Figure 6 Evaluated storage based solution

Figure 7 shows an example of the calculated performance indicators of a number of generated unique solutions.

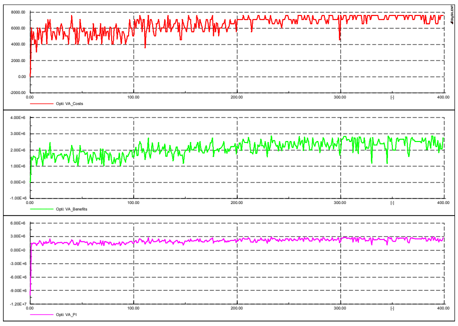

Figure 7 Performance indicators

VALIDATION OF THE TOOL

PLATOS is currently being validated by several partners within the GROWDERS project. The validation includes both the inner and outer loops of the software tool. The inner loops concern the power system analysis routines, the outer loops the optimization routines. The validation is conducted by means of measurement results acquired at the 4 test sites of the GROWDERS project. In figure 6 one of the test grids is depicted.

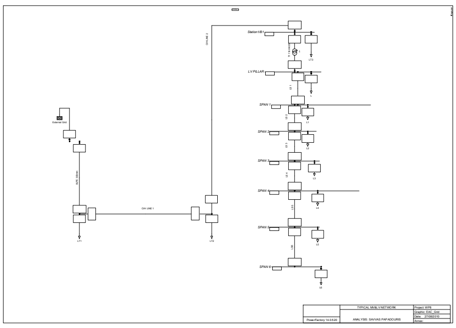

Figure 8 Test grid of EAC (Cyprus)

Initial validation results

Based on the initial validation results it can be stated that the tool operates in accordance with the functional requirements set by the project team. The tool is able to generate and assess large amounts of individual solutions during a prolonged time.

OUTLOOK

In the period to come additional functionality will be added to the PLATOS tool. This will make it possible to address other issues related to the use of storage. A typical example would be the issue of charging large amounts of electrical vehicles.Furthermore the models of the storage devices will be expanded in order to be able to model the behaviour of specific storage devices in more detail (e.g. Peukert effect). Attention will also be paid to speeding up the optimization process by adding additional optimization techniques.

CONCLUSIONS

An innovative storage planning and assessment tool (PLATOS) has been developed that can assist network planners to determine the optimal size, type and location of storage systems to be implemented in their electrical network. The PLATOS tool can help users to get a good insight in the pros and cons of specific storage applications in distribution networks and to develop storage application alternatives that fulfill predefined objectives without exceeding technical and economical constraints. Therefore PLATOS supports the efficient utilization and further deployment of sustainable energy.

REFERENCES

[1] www.growders.eu

[2] P.de Boer-Meulman, 2009, "Practical implementation of grid connected energy storage systems: the GROWDERS project", *ProceedingsElectrical Energy Storage Applications and Technologies Conference*

[3] R. Oliveira, 2009, "Increasing quality of supply of EDP through optimal and strategic distribution automation design", *Proceedings CIRED 2009*