

Integration of DG in MV-grids: challenges encountered by the grid operator

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INTEGRATION OF DG IN MV-GRIDS: CHALLENGES ENCOUNTERED BY THE GRID OPERATOR

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ABSTRACT

In the Netherlands horticultural areas are developed and in these areas a large number of CHP-plants are installed or will be installed in the near future. To facilitate all possible expected power flows the distribution grid as well as the transmission grid needs reinforcements. To meet the obligations of the legal and regulatory framework the grid planning has to be done in a proactive way. In this paper grid planning of a medium voltage grid including large penetration of CHP-plants is described. It is illustrated with an existing case study.

INTRODUCTION

Today's power systems are undergoing major changes. These changes are driven by both economical and environmental issues such as liberalization of energy markets, unbundling of utilities and an increase use of renewable energy sources. Based on the European policy that by the year 2020 20% of the total consumed electrical energy is generated by renewable and distributed energy resources, it is expected that the amount of small generation units further increases.

DG in the Netherlands

In the Netherlands the growth of distributed generation (DG) mainly consists of small Combined Heat and Power-plants (CHP) and wind turbines. In the early nineties local energy companies installed CHP-plants in the green houses [1]. These CHP-plants were mainly heat driven and the generated electricity was used for loss compensation and peak-shaving. Halfway the nineties the flue gas scrubber entered and CHP-plants start producing CO₂ as well. Due to the liberalization various energy markets were established and it became more and more interesting to produce heat and CO₂ in combination with electricity. In 2004 the illuminated crops starts to increase rapidly which has lead to an enormous increase in CHP-plants. In figure 1 an overview of development of CHP-plants in the horticultural sector in the Netherlands is given [2]. It can be seen clearly that the last couple of years the total installed power is more than doubled.

Problem definition

Local government has designated rural areas where horticultural activities can be developed. In these areas greenhouses are built and each greenhouse contains a CHP-plant.

Because of the clustering of horticultural activities the

CHP-plants are clustered as well, leading to a high penetration level of CHP-plants in the local Medium Voltage grid (MV-grid) (>100 MW). During the development of a horticultural area the grid operator receives many requests for a connection.

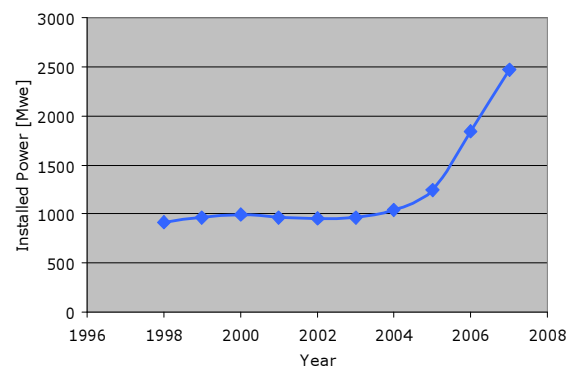


Figure 1 Installed CHP-plants in the horticultural sector

In the Dutch legal and regulatory framework it is stated that the grid operator is obliged to deliver a connection to the local grid within eighteen weeks. For a single connection eighteen weeks might be reasonable. However, for multiple connections this delivery time is almost impossible. Besides the delivery time of the connection, the capacity of the local MV-grid as well as the sub-transmission grid is limited. Hence to make the transport of local generated electricity possible, grid reinforcements of the MV-grid and the sub-transmission grid is necessary. In some cases even the high voltage grid (HV-grid) needs reinforcements. In figure 2 an overview of the planning and realization periods of various grid reinforcements is given.

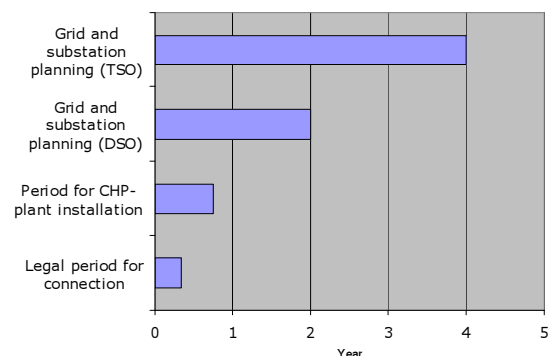


Figure 2 Planning period of various grid reinforcements

It becomes clear that in the horticultural areas the grid operator cannot just respond to a request for a connection. Then the obligations of the regulatory framework cannot be met and long term transport limitations have to be enforced. To prevent these long term transport limitations and meet the obligations of the regulatory framework a proactive approach is needed. In this paper the challenges STEDIN has encountered during the grid planning stage are discussed in detail and will be illustrated with an existing case study.

GENERAL APPROACH

The development of efficient MV-grids in horticultural areas is a complex problem and cannot be solved at once. The first step in the grid planning is to make a subdivision of the problem. In this project three levels are defined [3]:

- Level 1: Impact on transmission grid
- Level 2: Impact on sub-transmission grid
- Level 3: Physical connection to the MV-grid

As mentioned earlier and also shown in figure 2 the legal period for a connection is eighteen weeks. The period to complete the installation of a CHP-plant is about nine months. Provided that the market gardener inform the grid operator at the start of their installation period, even multiple connections can be made in this nine months, and this issue is not further considered in the grid planning. Level 1 and level 2 are further discussed in the next section.

To plan the grid in a proactive way scenarios have to be established. These scenarios are based on expected growth of load or number of CHP-plants in a certain area as well as technical and economical developments which can influence this growth. With the aid of these scenarios bottlenecks in current MV-grids and sub-transmission grids can be recognized. For each bottleneck in each scenario alternative grid designs are generated. These alternatives are generated in such a way that the expected growth of CHP-plants in each scenario is covered. The alternative grid designs are checked with boundary conditions. The boundary conditions are conditions which can restrict the possible solutions. Examples of boundary conditions are e.g. minimum realization time, grid operator constraints or limited investment funds for the grid operator. In the grid planning stage, for each scenario this approach results in a plan. When for each scenario a probability is determined an optimal plan or combination of plans can be established, using statistical techniques. The development of the horticultural area assesses what scenario has to be followed and what steps have to be taken by the grid operator. This approach is depicted in figure 3.

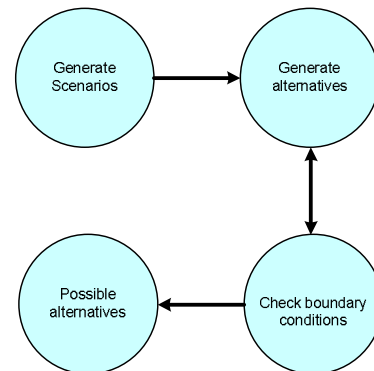


Figure 3 Overview of the grid planning stages

CASE OOSTLAND II

Oostland is an area where local authorities have decided that horticultural activities can be developed. At this moment in the project Oostland I some greenhouse are already built and a number of CHP-plants are already connected to the local grid. It is expected that in the next few years this area will be fully developed and the number of CHP-plants will increase significantly. In the former section a general approach is discussed. In this section this approach is applied on the case Oostland II. Because this case is a rather specific study the process and the results of this case are described in a general way only. The emphasis is on the challenges which the grid operator might encounter.

Project levels

The first step is to split up the problem in three parts. The particular levels for this project are depicted in figure 4.

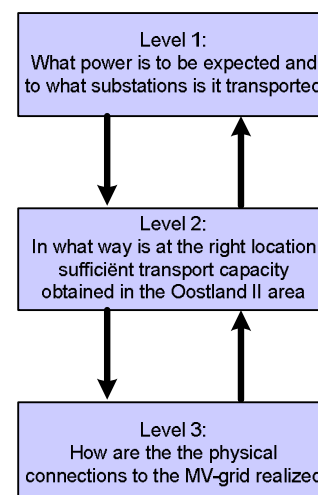


Figure 4 Subdivision of the problem of Case Oostland II

The first level deals with the total expected power and the impact on the transmission grid. In this level it is studied how existing substations can be extended and where new substations have to be built and how they are connected to the

transmission grid. The second level studies the sub-transmission and distribution grid in the Oostland area. At what locations are the CHP-plants expected and at what location substations of the DSO have to be built. Also of importance is to what substation of the TSO are the substations of the DSO connected to. In the planning stage both levels have an interaction with each other as shown in figure 4. The third level deals with the physical connection itself and, as mentioned in the former section, will not be considered in this paper.

Scenarios

For the grid planning four scenarios are developed. The scenarios are based on experience gained in comparable horticultural areas, new technological developments and an inventory of all connection requests in the Oostland area. An overview of the scenarios is given in figure 5.

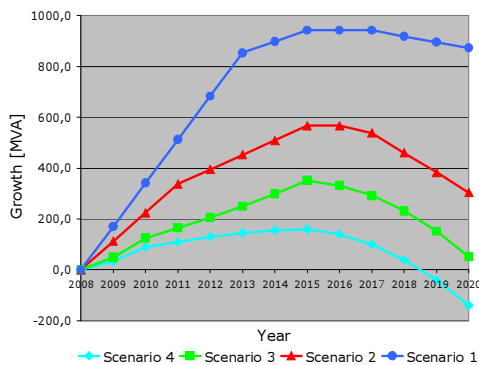


Figure 5 Overview of the scenarios of the Oostland area

Scenario 1

Scenario 1 is the absolute maximum scenario. In this scenario the politics stimulate the use of CHP-plants for heat and electricity generation. The market gardener will be stimulated also to supply heat for district heating outside the horticultural area. In the first couple of years the heat demand is growing however, in this scenario it is expected that after a period of time the heat demand decreases due to better insulated houses and offices. In this scenario the current district heating system is abandoned. The maximum installed capacity of CHP-plants is 940 MW

Scenario 2

This scenario represents the maximum growth in the Oostland area. In this scenario a reduction of the horticultural area is taken into account in the period of 2011-2015. It is also assumed that the current district heating will be stay in service. In this scenario the heat demand also decreases because of the reasons mentioned in scenario 1. In this scenario the maximum installed capacity of CHP-plants is 570 MW

Scenario 3

Scenario 3 has drawn up an inventory amongst market gardeners in the Oostland area. Based on this inventory a

prognosis has been formulated with a growth of 10% a year till 2015. In this scenario the number of CHP-plants decreases after 2015 due to new sustainable heating techniques like geothermal heating. The total power of CHP-plants is 350 MW

Scenario 4

The inventory of scenario 3 is also used to formulate a minimum scenario. In this scenario economical developments which discourage CHP-plants are taken into account. It is also assumed that after 2015 the CHP-plants will be no longer applied in the greenhouses. In this scenario the capacity of the total new installed CHP-plants is 160 MW

Alternative grid designs

To find an optimal solution for the connection of CHP-plants in the Oostland area alternative grid designs have to be generated. As mentioned earlier the Oostland project is split-up in three levels and for level 1 and 2 alternatives are generated. Starting point is that the generated alternatives have to be within the terms of reference of the grid operator. Therefore only alternatives in the category infrastructural adjustments are elaborated.

Without going into details for level 1 the following alternatives are generated:

- Extention of existing substations
- Build of new substation at TSO level
- Control of power via HVDC

For level 2 some alternatives are:

- Change of grid voltage
- Extention of current grid philosophy
- Application of DC in MV-grids
- Upgrade of grid components
- Build of new substations at DSO level

Boundary conditions

In order to assess what the optimal solution is boundary conditions have to be defined. Per scenario each alternative has been evaluated with all boundary conditions. In this project the boundary conditions are formulated:

1. Physical space: Is sufficient space available to extend existing substations and build new substations
2. Operation of the sub-transmission grid: All grids have to be designed and operated conform current grid code. The maximum number of transformers per substation is set to four.
3. Transport capacity have to be available within two years after receiving an order

The Dutch TSO has enforced some transport limitations. This has to do with exceeding the fault levels in some substations as well as congestion in parts of the transmission grid. In

figure 6 an overview of a part of the transmission grid of the province of Zuid Holland is shown. Also the location of the Oostland area is given. For the substations 5 & 10 the fault level is exceeded. Due to grid congestion no net export to the transmission grid is possible at substations 2-5 & 7. These limitations cannot be affected by STEDIN hence the transport limitation is formulated as a boundary condition.

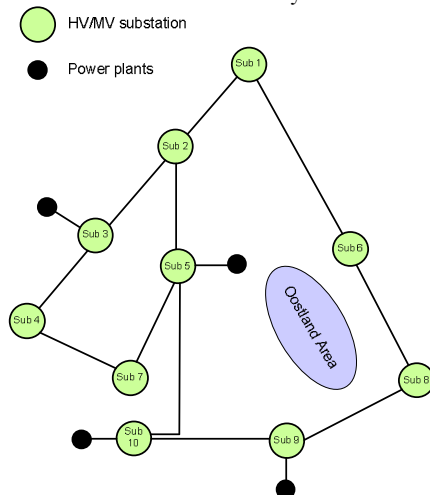


Figure 6 Overview of a part of the transmission grid

RESULTS

For both levels per scenario all alternatives are checked with the boundary conditions. Most unconventional designs proved impossible due to time constraints. At level 1 this has resulted in two alternatives:

1. The capacity of substation 2 and 9 is used to connect CHP-plants up to minimum load without export. The CHP-plants of the Oostland I project are already connected to Substation 6 and this substation has to be extended. In 2013 a new substation of the TSO has to be in operation.
2. The capacity of substation 2 and 9 is used to connect CHP-plants up to minimum load without export. Besides that substation 5 and 6 have to be extended. At a different location then in alternative 1 in 2013 two new substation of the TSO have to be in operation

At level 2 only one alternative has been selected. The existing 10 kV MV-grid will be extended and a new 23 kV grid will be built.

Per scenario for both alternatives a step-by-step plan is possible. The steps which have to be taken per scenario show a great similarity. A major factor in the step-by-step plan is the period needed to build a substation at DSO level and to build a substation at TSO level. In figure 2 it is shown that it will take two years to complete a DSO substation. Hence the first moment to dispose of the substation is 2010. Before that period the only feasible solution is the extension of existing

grids and substations. The same holds for substations at TSO-level. It takes four years to build a substation and in that period only solutions in existing TSO substations are possible.

Taking the above into consideration for this case the following decisions were made:

- Scenario 2 is taken as a reference
- Build of a new TSO substation
- Extension of three DSO substations
- Build of five or six new DSO substations
- Introducing a new voltage level of 23 kV for new MV-grids

The actual development in the Oostland area determines how fast the new substations have to be built.

CONCLUSIONS

General

Because of the development of horticultural areas the number of CHP-plants has grown fast the last couple of years. To provide all applicants a connection to the local MV-grid and make all power flows possible the grid operator has to develop the grid in a proactive way. In this paper it is demonstrated that with the aid of scenarios future bottlenecks can be assessed. To solve these bottlenecks alternative grid designs have been defined and for each scenario a step-by-step plan is established. Due to the fast developments of the horticultural areas on the one hand and on the other hand the long realization period for transmission grid project, feasible grid development at MV-level is mainly determined by the TSO substation extension.

Because of the scenario approach per scenario it is known what steps have to be taken. These steps can be admitted in the investment planning of the DSO.

Challenges encountered by the grid operator

The biggest challenge for the grid operator is to formulate various realistic scenarios and assessing what scenario will be followed. Moreover to complete the DSO substations in time the grid operator have to invest in advance. In this case for all scenarios the steps are more or less the same. Only the number of substations and completion period differs. Building DSO substations can be easily postponed when deviating of a scenario. The greatest remaining risk is to construct a cable connection in advance. There is a possibility to lay the cable in the wrong direction.

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