OPTIMIZATION OF REVENUES FROM A DISTRIBUTED GENERATION PORTFOLIO: A CASE STUDY

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ABSTRACT

Many companies are investing in energy production from renewable energy sources and are looking at ways to optimize their portfolio performance. The case study under consideration aims at maximizing the revenues from such a distributed energy generation portfolio, consisting of gas engines and a PV installation, by actively controlling the available flexibility within a cluster. The gas engines themselves and an on-site water treatment plant turned out to be flexible respectively in their electricity production and consumption. This paper presents the results of two simulation scenarios where each one has a different level of automation and discusses the technical as well as the economic outcomes of the analysis. The study turned out to be positive since there is a viable business case for actively controlling the available flexibility within the cluster.

INTRODUCTION

Group Machiels [1] has already invested a lot in energy production from renewable energy sources and they are still expanding their portfolio. Since they don't have a supply license themselves, but are bound by a contract with a retailer, there are certain considerations when managing their generation portfolio. VITO is supporting them, not only through studies, but also with the application of an agent based distributed control algorithm called IntelliGator™.

This case study tries to optimize the revenues from aggregated distributed generation (DG) on different sites by actively controlling the available flexibility within a cluster. The aggregated production can be seen as the production of a Virtual Power Plant (VPP) consisting of different power generation units [2].

The project of the case study follows a stage-gate approach and contains the following phases: demand response audit, simulation, implementation, operation and follow-up. To proceed to a next phase the milestone criteria of the current phase should be met. During the demand response audit, a first assessment of the economic potential is made and the available flexibility (of generation, load and/or storage) is identified. If the case under consideration seems both economically viable and technically feasible, the case will be assessed through simulations. The next steps are the implementation (without intervening with the installations) and the real-time operation where the control is actually implemented. When needed, follow-up actions will be initiated. Currently the on-site implementation is ongoing. The scope of this paper thus consists of the first two phases. The site that is being studied is currently a landfill site for industrial waste, but also consists of different closed landfill zones that were used to store municipal waste and industrial waste. A gas extraction and valorisation plant has been built to extract gas from the closed zones, arising from anaerobic digestion. The extracted gas is valorised in gas engines to produce green electricity for about 10.000 families. The leachate of the landfill is recuperated as clean water at the company's water treatment plant. Part of the electricity is used to meet the local demand of the site. The other and main part of the generated electricity is delivered to the public grid. For the sale of this electricity, the company has a contract with a retailer. Within the same contract, also generated electricity from a photovoltaic (PV) installation on another site of the company is sold, but the electricity injected to the grid is in this case very limited, since the main part of the electricity is consumed locally. The objective of this case study is to maximize the revenues from the combined injected electricity of both sites.

OPTIMIZATION PORTFOLIO

The revenues of the injected production (combined production from the gas engines and the PV installation) depend amongst others on the extent to which the real, injected production corresponds to the nominated production. The nomination is a flat monthly value. Based on the nomination, a nomination window is determined with the nomination value as the upper limit and a fraction of the nomination value as the lower limit. The settlement is done in time slots of 15 minutes on a monthly basis. The monthly revenues of the injected production are calculated using the following formula:

BF x LF x AV x P with BF = Balancing Factor
LF = Load Factor
AV = Available Volume (MWh)
P = Base price (€/MWh)

The Balancing Factor (BF) is a fixed factor <1.The Load Factor (LF) is a variable factor ≤ 1 and represents the extent to which the injected production approaches the nominated production. If the electricity production stays within the nomination window for every quarter, the Load Factor for that month will be 1. If the injected electricity is lower than the lower bound of the nomination window during certain quarters of the month, the Load Factor will decrease. The Available Volume (AV) is the injected production minus overproduction (production > nomination) whereby the overproduction is calculated on a quarterly hourly-basis. The Base price P is a yearly, fixed price.

In the formula, the Balancing Factor and the Base price are fixed values. To increase the revenues from the injected production the other two factors thus need to be optimized. Following measures will increase the revenues:

- Avoid overproduction (realized production > nominated production) on a quarterly hour basis to optimize the Available Volume.
- Avoid "too much" underproduction (realized production < a certain portion of the nominated production) on a quarterly hour basis to optimize the Load Factor.

If the grid injected electricity thus stays within the nomination window, the revenues will be optimized given the available landfill gas and solar power. At the moment an operator controls the installations manually to stay within the nomination window. Group Machiels has already done a lot of efforts to improve the control of their installations and the results of the last years show that they are getting better at it. Nevertheless there remains a potential for revenue optimization and the objective of this case study is to determine whether we can valorize this potential by applying automatic control to the onsite installations.

TECHNICAL ANALYSIS

In order to assess the automated control of the installations a couple of simulations, which will be discussed later on, are executed. The applied control algorithm is IntelliGator™ , which is an agent-based control algorithm for coordination in a smart electricity grid. It is capable of coordinating a large amount of units: distributed generators, responsive demand and electrical storage. An agent is a software or hardware computer system that is able to make autonomous decisions, to interact with other agents and reacts, reactively and/or proactively, to changes in its environment [3]. IntelliGator™ agents act as a representative of a producer or consumer device on a market. On this market, agents send in bids that represent the agent's demand/supply needs. All incoming bids are aggregated and an equilibrium priority is determined [4], [5].

Simulation models

The schema below gives an overview of the landfill site and the PV installation on the other site. WTP1, WTP2 and WTP3 are three water treatment plant (WTP) instances which clean leachate water coming out of a large buffer B1 and store the semi-cleaned water into a smaller buffer B2. After that, WTP4 cleans the water coming out of B2 and stores the clean water into buffer B3. Electricity is produced by the gas engines which use the gas extracted from the landfill in order to power the WTP installations and other local loads and to deliver the desired power to the public grid. In order to simulate the behaviour of the onsite installations, adequate models of the installations have been developed.

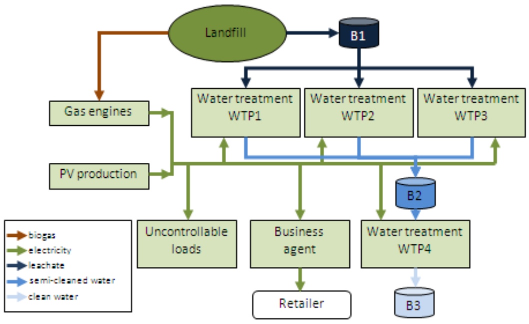

Figure 1: Technical overview Group Machiels site - B1 is a leachate water buffer. WTP1, WTP2, WTP3 and WTP4 are four water treatment plant (WTP) instances. B2 stores semi-cleaned water, B3 stores clean water

Photovoltaic installation

The solar panels are physically residing on another site but since the injected electricity from the PV installation and the gas engines are sold within the same contract it is necessary to take them into account. Measured production data from a 1 year period is used to simulate the PV production.

Gas engines

The gas engines are modelled as one large engine; Physically there are three but virtually they are controllable as one. The correlation between the meteorological conditions and the pressure maintained within the landfill, impacting the volume of landfill gas produced and offered for valorisation by the gas engines, is modelled in the simulations.

Non-flexible load

Non-flexible loads are modelled in two different ways dependent on the scenario. The scenario with controllable WTP installations uses randomly generated consumption data. Measured power consumption data from one full year is used in the non-controllable WTP scenario because this data already contains the consumption of the WTP units.

Water treatment plant

There are four WTP units. WTP1, WTP2 and WTP3 work in parallel and WTP4 is placed in series with them. The flow is constant for every WTP pump. Due to the constant flow the power consumption of the pumps depends on the pollution of the filters of the WTP installations. When the pollution rate of a filter reaches a certain threshold, the controlling agent will indicate that the WTP can be switched off in order to clean the filter. It is important to note that when a WTP unit is cleaned it still has a constant power consumption. Only two out of three WTP installations placed in parallel can run simultaneously. The other one is waiting, or being cleaned, until another one switches off to be cleaned.

Business agent

As opposed to all the models above the business agent doesn't represent a physical device, but is a pure virtual agent. It is responsible for keeping the injected power within the prescribed nomination window, as discussed in the Optimization portfolio section.

Simulation results

The objective of the automated control is to make sure that the injected electricity stays within the nomination window on a quarterly hour basis. There are two possible sources of flexibility, the flexibility of the controllable loads e.g. the WTP units and the flexibility of variable generation e.g. the gas engines, which can be used to achieve this objective. To vary the production of the gas engines the business agent is used. Every 5 minutes this agent adjusts its bid in order to stay within the nomination window. As a consequence of raising the business agent's bid, the gas engines will adjust their production. Shifting of WTP consumption can be done within certain boundaries. The flexibility depends on the state of the water buffers and the pollution of the WTP filters.

Two scenarios are executed. The first scenario starts from the current situation. In a second scenario the photovoltaic production is virtually increased compared to the existing situation since Group Machiels is considering expanding the PV installation. This allows defining whether the flexibility is sufficient to keep the injected power within the nomination window. The timeframe of each scenario is 1 year and for every scenario the results are compared to the actual figures obtained by the manual control of the installations over the same period.

Scenario 1: Current situation

As already mentioned, both the gas engines and the water treatment plant turned out to be flexible. Smart control of the WTP installations is complex because it is susceptible to human interpretation and the water treatment process is very sensitive. For example every fourth cleaning cycle needs to be an extensive one which requires a technician to be physically present at the site. Furthermore when stopping a WTP unit for longer than one hour treatment is needed to prevent formation of bacteria etc. As opposed to the gas engines, the WTP installations are currently not equipped with hardware for automated control. Therefore the automated control was first applied only to the gas engines within this scenario to see if the simulated injected power stays within the nomination range. An advantage when executing this simulation is the availability of load data (measured consumption data for the reference period).

Figure 2 shows which portion of the year the injected power stays within the nomination boundaries, which are represented by the black bars. The figure shows that the actual injection (without automated control) fluctuates too much to stay within the boundaries. A major reason for this is the unpredictability of a part of the load at the landfill site. In particular the WTP installations have a high rate of uncertainty. Their consumption pattern is dependent on the state of the water buffers and the degree of pollution of the filters. Adjusting the produced power of the gas engines manually doesn't compensate for the uncertainty of the load during every quarter of an hour.

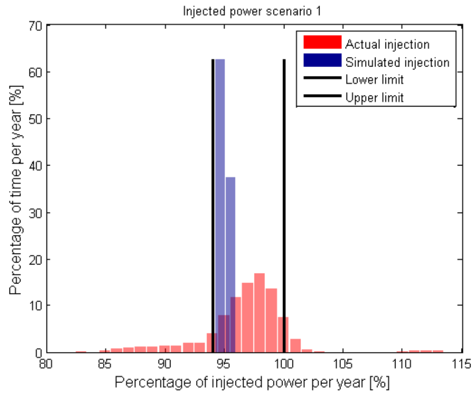

Figure 2: Injected power scenario 1 - Percentage of the time the injected power (actual and simulated) stays within the nomination window

Applying smart control to the gas engines enables to better correct for the difference between predicted and actual injected power. Every 5 minutes the requested power and consumption is adjusted to compensate for the mismatch occurred in the preceding 5 minutes in order to stay within the nomination window over a quarter of an hour.

The blue bars in Figure 2 show that the simulated injected power stays well within the prescribed boundaries during the whole year. It was a conscious choice to keep the simulated production very close to the lower limit of the nomination window. This ensures that the simulated production by the gas engines does not consume more gas than there was really available at the site. The results thus show that the gas engines in itself have enough flexibility to keep the injected power within the limits.

Scenario 2: Future situation - Expansion PV production

Group Machiels is considering to expand its PV installation. A first analysis showed that the gas engines don't have sufficient flexibility to cope with the increased PV production. Within this scenario the automated control was therefore also applied to the WTP units. The simulation is thus repeated for the situation with an extrapolation of the original PV production data and with the automated control applied both to the gas engines and the WTP installations. In this configuration the injected power exceeds the nomination as can be seen in Figure 3 for certain quarters. The expansion of the PV installation can thus not be counterbalanced on bright days by the control of the gas engines and the water treatment without causing overproduction. Meeting the requirement to stay within the nomination window can only be achieved with extra flexibility which fits into the VPP concept adopted by Group Machiels.

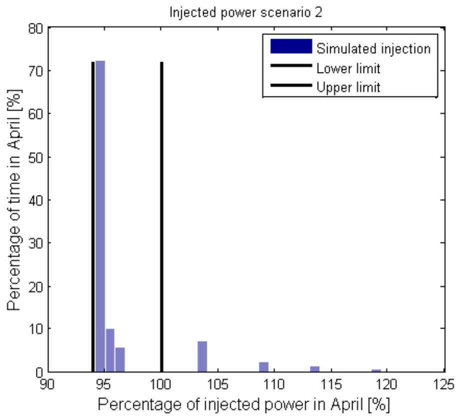

Figure 3: Injected power scenario 2 - Percentage of the time the simulated injected power stays within the nomination window

ECONOMIC RESULTS

For the economic analysis (for the current configuration) a full year is used as a reference. The simulation results show that it is possible to keep the injected production within the nomination window on a quarterly hour basis when only controlling the gas engines within the reference period for the current situation. This means that the load factor is 1 and the available volume is equal to the injected production for every month. The actual monthly revenues of the injected production are compared to the revenues that would have been realized if the gas engines would have been controlled by Intelligator™. Our economic analysis shows that about 2,5% additional revenues can be gained in the reference year. As already mentioned Group Machiels has already done a lot of efforts to improve their manual control and this analysis shows that by applying automated control they can fully maximize their revenues from the injected production. This shows that the relatively simple and robust Intelligator™ algorithm tops the best manual control.
In addition to higher revenues, other benefits can be identified; At the moment an operator controls the loads and generators manually to comply with the nominations. Personnel costs can thus be avoided by applying automated control. Also by applying the control algorithm some other processes, like fixing and sending the nominations, can be automated. On the other hand some initial investments will be needed both in hardware and software as in personnel cost to automate the control of the gas engines. These extra costs aren't yet taken into account in the analysis.
For the future situation scenario with expanded PV production, the simulation results showed that it wasn't possible to avoid overproduction and thus loss of revenue. Therefore it would be recommended to negotiate a new contract with the retailer before expanding the PV installation or to add flexibility.
This case study focuses on the optimization of the current contract for the two sites under consideration. The distributed control algorithm is designed for scalability; This offers opportunities for expanding the cluster. When the terms of the contract would be renegotiated and more sites with distribution generation would be added to the cluster, the aggregated profile could be operated as a Commercial Virtual Power Plant (CVPP) that takes the aggregated profile to the market to offer certain services (trading in the wholesale market, balancing of trading portfolios,…) as introduced by the Fenix project [6], [7].

CONCLUSION

In this case study, we have demonstrated that it is possible to keep the injected production (combined production of gas engines and PV installation) within the nomination range by real-time control of the available flexibility when controlling the gas engines based on one year's data and thereby gaining additional revenues.
The analysis has demonstrated that controlling the gas engines has an economic potential and it has been decided to go ahead with the next phases. Currently on-site implementation is ongoing. When the system is operational, opportunities of adding other sites with distributed generation to the current cluster, will be looked at.
The study also shows that adding substantial non flexible supply requires extra flexibility under the current retail contract.

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