AVOIDING GRID CONGESTIONS WITH TRAFFIC LIGHT APPROACH AND THE FLEXIBILITY OPERATOR

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ABSTRACT

While distribution grid operators have to ensure the power supply with well-defined quality constraints, future network nodes such as smart buildings or flexible generation units should be able to offer their flexibility (aggregated in distributed virtual power plants) to energy markets. In certain situations, market-driven operation can conflict with network restrictions on distribution level. Recently, the traffic light model has been adopted in many European smart grid discussions, which distinguishes between free market operation (green) and network restrictions (red). This work focuses on a concrete implementation of the yellow state, which uses local market incentives to avoid network restrictions in advance.

INTRODUCTION

With growing shares of distributed generation, conflicts between market and grid operation on distribution level can occur. While distribution grid operators (DSO) have to ensure the power supply with well-defined quality constraints, future network nodes such as smart buildings or flexible generation units should be able to offer their flexibility (aggregated in distributed virtual power plants) to energy markets. Recently, the traffic light model has been adopted in many European smart grid discussions. As shown in Figure 1 for the exemplified traffic light model of Technology Platform Smart Grid Austria, three network states are defined.

In the green state “Normal Operation,” the network is able to support free market operation. In the red state “Exceeding Limits,” the network operator needs to intervene directly in order to ensure safe network operation. In a novel yellow state hereinafter defined as “Needs for Operation,” a potentially upcoming congestion is avoided by congestion-motivated local market intervention.

Today, renewable energies (DER – distributed energy resources) are integrated into the grid physically whereas distributed Virtual Power Plants (VPPs) bid and trade the flexibility of aggregated prosumers into the market. In the context of this work a VPP is defined as an entity that aggregates producers and consumer and offer their services at different markets as a unified power plant.

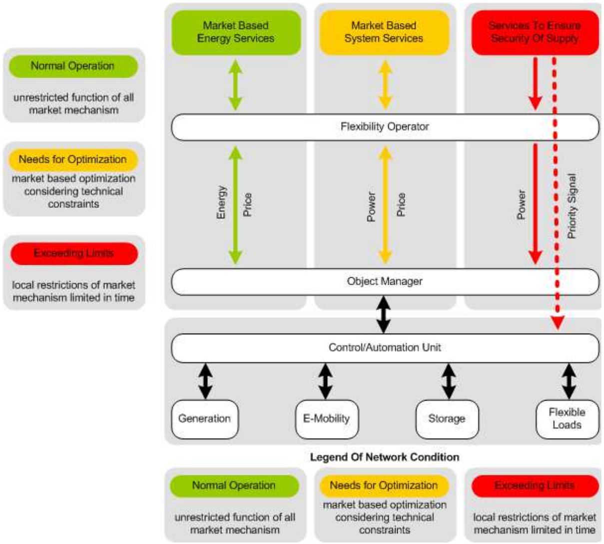

Figure 1: Traffic light model of TP Smart Grid Austria [1]

VPPs aim at maximizing the economic benefit and therefore cannot consider local grid states. Thus, neither the DSO, the DER operator, nor the VPP operator have an overview of what is going on in the grid and its connected prosumers. The nodes consume or produce energy according to their internal behaviour patterns or based on contracts with one of the VPPs. The DSO is able to operate its Smart Grid e.g. by controlling a secondary substation’s on-load tap changer transformer (OLTC) to avoid voltage band violation in the feeders. As long as this is sufficient to operate within the limits, the nodes and the VPPs can continue undisturbed. In case of a violation, only measures like disconnecting nodes are available to the DSO to guarantee grid quality. This is an undesired situation as this interferes with the market oriented behaviour of the nodes. Not reacting would lead to a violation of the technical duties of a DSO. Thus, a solution is needed that mediates between the two contradicting goals market orientation and grid quality.

A new role, the Flexibility Operator (FlexOp), can put incentives or requests to start economically based mechanisms to keep the grid in a stable and reliable condition, as well as to minimize the economic loss for flexibility providers. The balance of these two aspects is a central topic of the concept. The FlexOp is developed and approved in the ongoing Austrian research project INTEGRA and should be tested in the field within the Smart Grids Model Region Salzburg (rural setting) [7] as well as Seestadt Aspern (urban setting). Different conditions for balancing in the grid have to be considered. The main focus of the FlexOp is on the yellow grid state. By buying flexibilities from smart buildings, the FlexOp tries to avoid the red state as long as possible. This article focuses on the realization of the mechanisms required to implement such a yellow network state. The necessary market concepts, the ICT architectures and results from ongoing projects are discussed.

PROPOSED SYSTEM ARCHITECTUR

A simple view on how to differentiate the three states in the traffic light model is to define two arbitrary sets of thresholds. The first divides the green and the yellow state; the second, less strict threshold defines the border between yellow and red. The measures for the yellow and the red state as well as the chosen values may differ from project to project. Recent proposals like [2] differentiate the non green states yellow and red by the type of used measures. If available flexibilities are sufficient to counter current grid quality violations, the grid is in the yellow state. Otherwise measures like active power constraints have to be used to stabilize the grid – this is the red state.

We propose to extend this definition with forecasts in the yellow state. In case of a predicted quality problem, the FlexOp uses market mechanisms to buy flexibilities for this time window. If sufficient flexibilities have been attained, the red state is successfully avoided.

Now a clear distinction between the three states is achieved. For the current moment only a distinction between no problem exists (=green) and grid quality violations detected (=red) is considered. For future points in time a forecast evaluates if countermeasures are necessary (=yellow). In the green state no restrictions and actions are necessary. In the yellow state market mechanisms are active to avoid a future red state. And finally, during red state situations the DSO can restrict consumers and producers based on technical criteria.

The red grid states measures are performed by a Low Voltage Grid Controller (LV Controller, see e.g. [3]). It uses meter readings and other sensory information to detect red state situations. Possible actions are changing of the tap position of the transformer and Q/P set points for flexible loads. The low voltage FlexOp renders new forecasts and buys flexibilities in case of a yellow state repeatedly. Each prosumer/flexible load may interact with a cross-regional VPP any time.

Figure 2 shows the basic system architecture. Next to the above described components LV Controller, FlexOp LV, and on load tap changer, several other components are important for the discussed architecture.

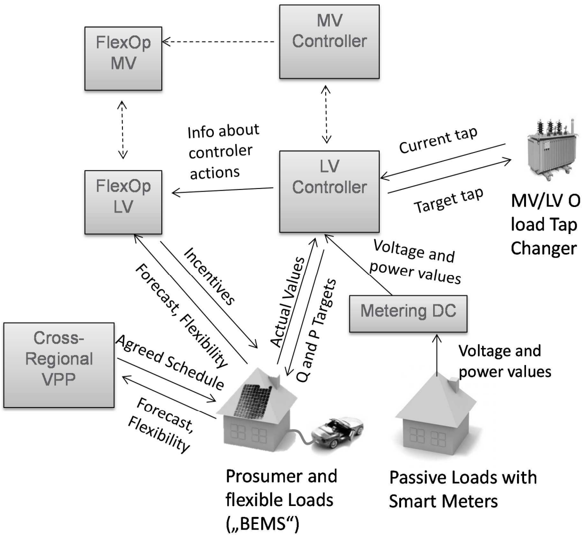

Figure 2: System Architecture

The flexible load/prosumer is defined as a component that is able of demand side management and demand response. For this purpose it might be equipped with a building energy management system (BEMS). Passive loads cannot be influence by the LV Controller or the FlexOp LV. Nevertheless, its smart meter readings can be used as input for the control algorithms. Depending on the used communication medium, a metering data concentrator is necessary (e.g. in case of power line communication). Active loads can sell their flexibilities to a cross-regional VPP.

The interaction – FlexOp and Controller – in the low voltage grid is mirrored by similar components in the medium voltage grid. The MV Controller can influence the HV/MV OLTC. Further, the MV Controller has to coordinate the actions taken with the affected LV Controllers. Otherwise the system may get instable.

The sequence diagram (Figure 3) shows the high level interaction of the components in the low voltage grid. In each time interval (e.g. 15 minutes) this sequence is repeated. It starts by collecting available sensor information. Smart meter values are forwarded to the OLTC/LV Controller and from there to the FlexOp. This guarantees that the FlexOp and the LV Controller operate on the same set of data. The buildings equipped with a BEMS first perform a self consumption optimization. The excess flexibilities are sold to a VPP. Based on this interaction, the BEMS generates a load forecast and forwards it to the FlexOp. There, all forecasts are aggregated and enriched by the meter readings. The resulting gird state estimation is then used by the FlexOp to buy sufficient flexibilities to counter future grid quality problems. In case of current grid quality problems, the FlexOp calls upon bought flexibilities to counter them. Due to the changed internal state of affected flexible components their BEMS needs to update its optimization.

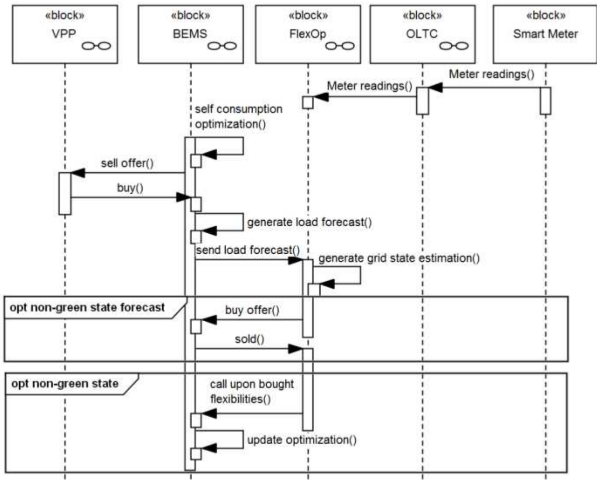

Figure 3: Sequence Diagram – FlexOp

To summarize, a FlexOp needs to include the following functions: communication with one OLTC and many BEMS (or equivalent), a market platform where the BEMS can offer and sell their flexibilities for the local market, a grid state estimation, aggregation of provided forecasts, and orchestration of the counter measures.

A direct communication between FlexOp and VPP is not intended. Each BEMS has contracts with one or many VPPs. Each VPP has contracts with many BEMS in many different grids. Thus, if the FlexOp tries to find a global optimum in coordination with all VPPs a lot of coordination effort is necessary for the rare event of a yellow grid state at every point in time. Further, it is very likely that a global optimum cannot be found due to many different and diverting optimization functions.

During one iteration of the sequence diagram only one round of trading takes place. Thus, it can happen that after detection of a future problem not enough flexibilities have been bought to counter it. The reasons for this can be that the FlexOp has not offered enough, only a subset of possible BEMS have been invited to the auction (e.g. the best three nodes), or not enough flexibilities are available at all. The last possibility will lead to a red grid state. The first two can be countered by another auction in the next iteration. By offering more and invitation of less optimal nodes the FlexOp can try to gather the necessary amount of flexibilities.

DISCUSSION AND ALTERNATIVES

The proposed system architecture adds significant complexity to distribution grid operation in network segments, where application of a Flexibility Operator makes sense compared to network reinforcement. In order to reduce this complexity, at least the following two aspects should be considered:

1. The function “Flexibility Operator” is only necessary if network restrictions in a specific distribution segment result in regular active power shedding and therefore disadvantage of affected generators. Grid controllers using intelligent voltage control schemes (see e.g. [3]) can deal with the situation alone as long tap changer transformer and reactive power management is sufficient.

2. The settlement between FlexOp and flexible resource (load or generator) can be simplified. In a basic setting, the FlexOp can retain to an informing role, warning about network restrictions in advance and leaving its resolution to an open-loop reaction of flexible resources on this information. This scheme is similar to the design of some demand response schemes in the U.S. (e.g. [4]).

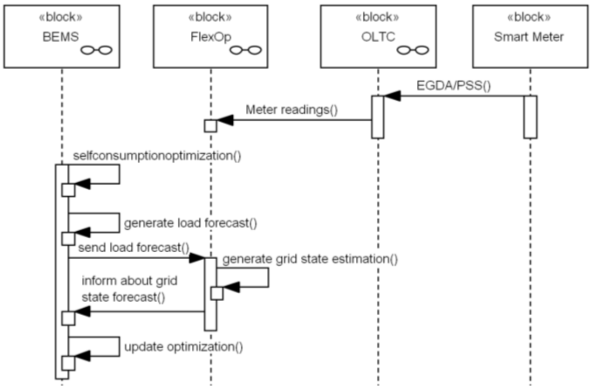

Figure 4: Sequence Diagram – Information only

A number of alternative approaches are currently under discussion. The analysis of the flexibility operator concept in the Austrian research project “SGMS INTEGRA” is conducted in close cooperation with the German “In2VPP” sister project[1]. In2VPP deals with the same issue of cross-regional market organisation on one hand and technical integration of renewables in local distribution grids on the other. In2VPP does not include a flexibility operator, but rather distinguishes between “economically optimised” and “technically optimised” virtual power plants (VPPs). While economically optimised VPPs offer their services on cross-regional markets, technically optimised VPPs offer regional products for distribution network operators.

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[1] See also *http://www.in2vpp.de/*, last visited 03/2014, in German language only

This can include regional aggregation, but can also be restricted to a very local case such as reactive power provision by a specific generator. Due to the low number of participants in such regional network service markets and the specific nature of the service (e.g. voltage control), it can be expected that these services will rather be bilaterally be agreed on.

While in INTEGRA, the FlexOp takes over the two functions “identification of bottlenecks” and “activation of flexibilities”, in In2VPP the distribution grid operator identifies bottlenecks but activates flexibilities only by means of a technically optimized VPP. In both approaches, interventions from the technical side (FlexOp or technically optimised VPP) might intervene the schedules agreed between flexible resource and economically optimised VPP. This is an open issue and will be further studied in both projects.

Further related work is often motivated by electric mobility and its network integration [5], dealing with approaches ranging from clearing-house concepts [5] to shadow prices for individual distribution lines [6].

OUTLOOK AND CONCLUSION

The challenge in the context of harmonizing market and grid driven operation is to find an appropriate level of pragmatic solutions, in order to realise such a complex scheme. INTEGRA tries to solve this by finding a concrete environment of application in the context of the Salzburg model region for Smart Grids [7]. The FlexOp concept will be implemented in this framework and demonstrated as a proof of concept. In parallel, the sister project In2VPP will proceed with its alternative solutions. A full comparison of both approaches will be available after both projects have implemented their pilot installations in 2015.

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