EVOLUTION OF DSO CONTROL CENTRE TOOL IN ORDER TO MAXIMIZE THE VALUE OF AGGREGATED DISTRIBUTED GENERATION IN SMART GRID

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ABSTRACT

This paper presents how implementing the new concept of aggregating a portfolio of DER, requires DSO and TSO control tools to be adapted. DER aggregation requires the coordination of numerous small generation units, that are too small to individually bid on energy markets or provide ancillary services.
This work was produced by the FENIX project. This project is a collaborative R&D project, partly funded by the European Commission within the 6th Framework Program for Research, that aims at demonstrating the value and the feasibility of the concept of DER aggregation.

INTRODUCTION

A large penetration of Distributed Generation (**DG**) and Distribution Energy Resources (**DER**) into distribution systems using a "fit and forget" approach is likely to lead to high investment costs for system users and network operators. Offering DER access to electricity markets and ancillary services to the distribution grid, would develop new value streams for power system users, when the actual findings will decrease with the development of the technology. However, a significant participation of numerous small generators to electricity markets, without any visibility for power system operators, could jeopardize the power system security and safety.
DER participation and contribution to electricity markets needs to be taken into account by control engineers when they monitor and control the grid. TSO and DSO will have to perform new activities like real-time voltage control using aggregated DER. However, the diversity and the complexity of new critical situations require control engineers to anticipate constrained situations in more efficient ways, considering the next periods of time:

- A day-ahead: to schedule the next day operation plan. Operational planning tools will be adapted.
- A few minutes ahead: to detect the critical situations before they occur. Control engineers will be warned and solicit aggregated DER reserves.

The paper shows that new DSO activities may be much more intimately integrated in market mechanisms than today. An analysis of the impacts on grid operation has been performed and we focused their description on situations that could be experienced by DSOs:

- Aggregated DER participation to electricity market.
- Advanced monitoring and activation of aggregated DER reserves.
- Real-time Volt and VAr Control (**VVC**) with aggregated DER.

DEFINITIONS

A Virtual Power Plant, **VPP**, is a flexible representation of a portfolio of smaller generators and demands. It creates a single operation profile from a composite of parameters characterising each contributor to the portfolio. The VPP is characterised by a set of parameters usually associated with a traditional transmission connected generator, such as scheduled output, ramp rates, voltage regulation capability and reserves. Furthermore, as the VPP also incorporates controllable demands, parameters such as demand price elasticity and load recovery patterns are also used for characterisation of the VPP.
A Commercial Virtual Power Plant, **CVPP**, is a type of VPP. A CVPP has an aggregated profile and output which represents the cost and operational characteristics for the DER portfolio. The impact of the distribution network is not considered in the aggregated CVPP profile. Services provided by a CVPP include trading in the wholesale energy market, balancing or trading portfolios and provision of services to the SO. The operator of a CVPP can be any third party/Balancing Responsible Party (**BRP**) with market access.
A Technical Virtual Power Plant, **TVPP**, is a type of VPP. The TVPP consists of DER from the same geographic location. The TVPP has an aggregated profile which includes the influence of the local network on DER portfolio output as well as representing DER cost and operating characteristics. Services from a TVPP include local system management for DSO, as well as providing TSO balancing and ancillary services. The operator of a TVPP requires detailed information on the local network, typically this will be the DSO. The TVPP provides visibility of DER to the distribution network to the TSO, allowing DG and demand to contribute to the transmission system management activities.

GENERAL FENIX ARCHITECTURE DIAGRAM

Figure 1 shows one of the possibilities of general architecture applied in the Fenix project. This general architecture could be adapted to take into account the specificities and the particularities of the systems such as, the existing functional architectures of the DER owners, Energy and Distribution utilities and also the local regulatory frameworks. It was designed such in order to:

- Embrace peculiarities of each European country.
- Optimise the changes in the business of the energy supplier and distribution operator by the TVPP.
- Optimise the impact on the existing information systems.
- Optimise the number of interactions between the different actors.

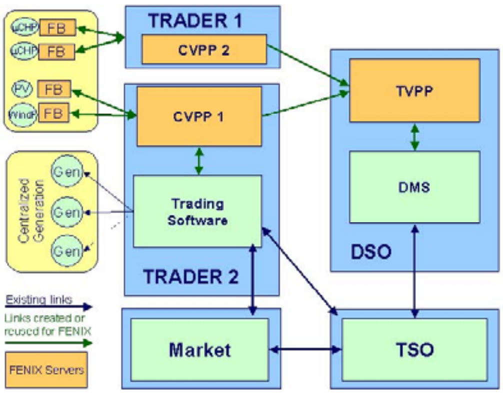

Figure 1: General Fenix Architecture Diagram

New equipments with their own applications will appear (see Figure 1):

- Fenix Box (**FB**) server, that includes the applications to aggregate loads and generators and ensures an optimal use for their owner.
- CVPP server, that carries the scheduling and energy optimisation functions for DER units.
- TVPP application, in the DMS server, that includes the applications validating the generation schedules and may amend them in order to address voltage and current constraints.

Traders, DSOs and TSOs Information Systems must be adapted.
The CVPP has the following functionalities:

- Builds the day-ahead schedule,
- Sends the set points to the DER Units.

Three types of Fenix Boxes have been considered:

- Type 1: Smart meter data concentrator that provides status and metering data.
- Type 2: A Box providing status and metering data and controls active and reactive outputs taking into account the technical feasibility.
- Type 3: A box allowing the communication with a wind farm or a DER controller.

The UML actors diagram (see Figure 2) describes the links between the FENIX actors. Associated link named *"Communicate"* allows to identify the communication of the FENIX's sub-entities. The left side of this diagram (CVPP, Market, DER...) illustrates the commercial entities and DER. The right side (TVPP, DMS, TSO, ...) illustrates the technical entities and networks responsibles. In the centre (modelled by an abstract actor), the VPP, main concept of FENIX, includes the CVPP and TVPP entities. The communication link concerns only the Distribution Energy Management System (**DEMS**) of the CVPP and the DMS of the DSO.

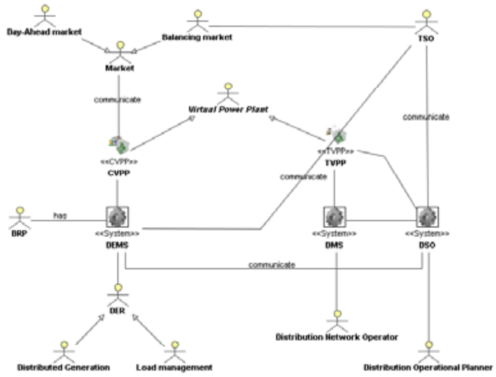

Figure 2: UML Actors Diagram

CVPP FUNCTIONALITIES

The DER units are grouped due to commercial aspects in the CVPPs. All the CVPP functionalities haven't been tested in the experimental phase.
The DER's portfolio, for a given CVPP, is already set up. The CVPP must allows the DER owner to maintain technical parameters and to declare planned outages on his equipment.
For the demonstration, the CVPP needs the following functionalities:

- Maintenance and submission of static physical characteristics of DERs.
- Administration of planned outages and non-planned outages on a long, medium and a short-term base.
- Forecasting of generation based on weather data.
- Forecasting of demand based on profiles.
- Administration of outages of demands.
- Generation of the bids for each DER.
- Submission of the bids to the market and of the balancing offers to the TSO.
- Re-optimising and rebalancing of real-time generation to meet physical reference schedules and therefore reducing imbalances.

The CVPP will sell energy provided by the DERs to the wholesale market. It can sign bilateral trades with other market players or place the energy blocks on the market. The traders need the following functionalities to communicate with the day-ahead market and with the balancing mechanism:

- Flexible administration of physical trades.
- Evaluation of potential risk of a trade portfolio against price forward curve.
- Possibilities of bilateral communication between the CVPP/Trader, the day-ahead market and the balancing mechanism.
- Meter reading.

TVPP FUNCTIONALITIES

The TVPP is a part of the SCADA / DMS (Distibution Management System) of the network control system. One of the functionalities of the TVPP is to perform the validation of the day-ahead base schedules of the CVPPs. All the functionalities haven't been tested in the experimental phase.

The TVPP receives the day-ahead base schedules from all CVPPs. The communication between the CVPPs and the TVPP is based on the existing communication protocols (web based or any other). All schedules are available to the TVPP at a defined time. The DSO performs the validation of the base schedules via the User Interface of the network control system.

The TVPP has two main functions:

- Feasibility check of the base schedules within the distribution network (based on the forecasted situation of the next day).
- Propose remedial actions to provide a feasible combination of schedules and network configuration, in case of problems detected.

The TVPP has to group the involved DER units forming the CVPPs due to topological aspects. All DER units topologically correlated to an infeed HV/MV transformer are assigned to the network area formed by this transformer. The base schedules are validated on a time step basis. They are checked for each network area in which DER units of the CVPPs are located. When the check shows problems arising in the network, remedial actions are evaluated whereby the network is kept within limits. The remedial actions cover:

- Topological changes in the network.
- Changes of the setting of voltage controllers in the network.
- Changes of scheduled generation values of DER units.
- Load shedding.

As DSO must be neutral towards the given schedules of the CVPPs, the modification of the schedules has, typically, lower priority. Consequently, any change has an influence on the neutral standpoint.

Conversely, the DSO should be neutral towards the customers. All customers have to be supplied with voltage. Therefore load shedding must only be considered at last resort.

Typically, the remedial actions of the DSO will thus be concentrated on distribution network internal manoeuvres like network reconfigurations and changes of voltage controller settings. Only when these actions are insufficient to avoid problems or are not practicable other types of action will be considered.

The remedial actions for one time step and one area are arranged under the form of a switching sequence.

The validated schedules of the CVPPs are presented to the DSO and are revised by the DSO using the TVPP. The TVPP prepares the validated schedules including the remedial actions. Additionally a single schedule is generated and presented which contains the revised scheduled generation for each DER unit and the switching sequences for the remedial actions. When the validated schedules of the CVPPs are accepted by the DSO, the DSO triggers the transmission of the validated schedules of the CVPPs to the TSO.

The generation schedule and possible flexibilities at the connection busses between the transmission and the distribution network are sent by the DSO to the TSO for technical validation. They are available at the same time as the base schedules of the CVPPs.

The schedules, validated by the TVPP and by the TSO, can be executed the next day by the CVPPs. The DSO has to observe the execution of switching procedures at the appropriate time.

To check the proposed switching sequences some time before their execution whether they are still valid due to unexpected events or changes in the network, the TVPP is used in revise mode. The DSO launches the TVPP to revise the DSO-schedule, starting with the time of the trigger. The TVPP generates the updated switching sequences for the time steps following the time of the trigger until the end of the schedule.

The TVPP needs the following functionalities:

- Evaluation of the feasibility of the scheduled generation values of the DER units derived from the basic schedules from the CVPPs .
- Planning of corrective measures in case of incompatibilities in the distribution network caused by the basic schedules.
- Validation of day-ahead schedules.
- Revision of the DSO schedule of the actual day;
- Evaluation of the time with the maximum power system load which has to be considered for further calculations.
- Management tool of switching procedures. The switching procedure which performs the reconfiguration of the network in a safe way. The calculated values will adjust in the network after the execution of the switching procedure. They consist of:
  - Comments describing what happens with the proposed commands.
  - Switching commands for load shifting and DER unit shifting by changing the topology of the network.
  - Switching commands for capacitors.
  - Setting commands for voltage controllers (On-Line Tap Changers (**OLTC**) and voltage regulators).
  - Setting of scheduled values of DER unit generation.
  - Switching commands for explicit load shedding.

DSO needs a VVC to optimise the voltage in the network.

The VVC application is a part of the TVPP. It helps the user manage and optimise constraints. VVC algorithm is a numerical optimisation algorithm that takes into account objectives and constraints. Within the numerical optimisation language, the word *"constraint"* means that the optimisation process can't compute a solution that exceeds limits defined by this constraint. This more flexible VVC system consists of a coordination of local self-adjustable voltage control. Using the measurement of Voltage and Currents, VVC determines the optimal set point for each component (DER, capacitor banks and OLTC).

CONCLUSION

The development of DER connected to distribution systems and their poor integration into electricity markets and systems, is the fundamental driver for FENIX project. This integrated European project aims to demonstrate Virtual Power Plant concepts, an aggregation of DER on distribution power systems, can:

- Provide services to support effectively the power systems such as conventional centralized generation.
- Improve the revenue of the generators under electricity markets requirements.

The participation of DER to electricity markets needs to be taken into account by control engineers when they monitor and control the grid. Transmission and distribution operators will have to perform new activities such us the real-time voltage control using aggregated DER. However, the diversity and the complexity of new critical situations require control engineers to anticipate constrained situations in a more efficient way:

- A day-ahead of time: The participation of DER into electricity markets needs to be taken into account to plan the next day operation (normal grid configuration, backup configuration, generation schedule). Operational planning tools need to be adapted or developed for that purpose.
- A few minutes ahead of time: Critical situations need to be detected before they occur. Control engineers need to be warned, in an appropriate manner, to solicit aggregated DER reserves.

The general architecture can be applied in each European country taking into account their particularities. The studies identified how the distribution system operation would have to be adapted if VPP were to be implemented. Early results of these use-cases show some interesting requirements for software applications such us advanced monitoring, optimal power flow and real-time state estimation that require new data exchanges. It also shows that the Distribution operators' traditional tasks will have to be extended to include new functions, but they will be greatly aided with increased visibility of DER, and analysis tools to forecasting and assessing the power system management risks.

The paper is a roadmap detailing how the VPP concepts would fit into different stages of the next electricity evolution. It shows also that new DSO activities may be much more intimately integrated in market mechanisms than today. An analysis of the impacts on grid operation was performed. Special care was given to the description of these impacts on three families of situations that could be experienced by DSOs:

- Aggregated DER participation to electricity market.
- Advanced monitoring and activation of aggregated DER reserves.
- Real-time VVC with aggregated DER.

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