INNOVATIVE OPERATION WITH AGGREGATED DISTRIBUTED GENERATION

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ABSTRACT

European distribution utilities are facing a significant development of Distributed Energy Resources (DER). Initially, DER has been connected using a "fit and forget" approach which is no longer appropriate as soon as the penetration of DER becomes significant. Size, intermittence and actual non-dispatchability limit DER units' ability to become active players in an open electricity market. Besides the economic advantage of integrating small generators into the electricity market, integration of aggregated DER may also offer new services to the grid. Aggregation of small generators and controllable loads through a "Virtual Power Plant" (VPP) may give an opportunity to small units to reach mandatory volumes of power to be economically significant, and coordination to offer capability of grid services. Multiple DER coordinated could not only participate to provide ancillary services (active power reserves for frequency control, reactive power reserve for local voltage control, black starts, etc.) that ensure stability and safety of the power grid, but also new customer services for power quality, communication or energy businesses.

A VPP would thus provide valuable support to grid operators, offer new business opportunities and increase competitiveness in electricity markets, and consequently favour a smart integration of DER in the system.

An European Commission integrated R&D project called FENIX, which includes utilities, manufacturers, research institutes and academics, aims to verify the feasibility and value of the VPP concepts, and finally demonstrate prototypes of Virtual Power Plants during 2009.

Physical implementations of such concepts require a rethink of traditional distribution operations to permit communication, command and control of VPPs to be coordinated with distribution. The VPP demonstrations illustrate the value of aggregating generators and loads. Scenarios include industrial controllable loads and several significant DER on a Spanish MV distribution network commercially aggregated by a VPP, and also a British town with a significant amount of small scale LV generation units. The scenarios describe how the generators could be coordinated and operated to respond to electricity markets and operator needs. Specifications of innovative usage of DER, described in scenarios, will be defined, developed and finally implemented in operating software systems for the prototype VPPs.

This paper presents the general concepts of VPP developed in FENIX, and then focuses on the consequences for the Distribution System Operators (DSO) and their need for active power system management, and the innovative functionalities that DSO tools will have to perform. It will finally present two case studies to be carried out one in the United Kingdom and the other in Spain to demonstrate parts of the VPP concept.

1/ BACKGROUND

European energy consumption (including electricity) has increased tremendously over the last decade and is still expected to double by 2035, with serious negative impacts on our environment (CO_2 emissions).

The Kyoto Protocol commits European countries to reduce greenhouse-gas emissions by 8% in 2012, relative to the levels emitted in 1990, promote energy efficient technologies and utilise renewable energy sources that will reduce CO_2 emissions.

The DER is defined by CIGRE Working Group 37-23 as non predictable, non dispatchable small generation units (nominal power below 50 MW), connected to distribution power systems. This definition will include most renewable energy sources (except large hydro plants over 50 MW).

Most distribution networks are "passive", designed radially with no consideration for generation connected along the feeders, and very little consideration for any type of demand-control or network restoration automation.

DER connection philosophy is based on a "fit and forget" approach, designed to comply with the traditional "passive" distribution power systems.

In order to obtain a DER connection, the generator has to comply with various national grid codes. These technical and operational requirements are based on decrees and ministerial orders. The technical requirements for grid connection of generators are quite similar all over Europe, however, the ways to manage grid reinforcement to allow the DER connection to comply with the requirements, may differ: charged to the DSO, split between TSO and Producer, or entirely charged to the Producer. In France, generators pay for the reinforcement costs, whereas in Germany and the UK that favour DER development, the costs are split. As a consequence, European utilities, including Iberdrola and EDF Energy, are facing a significant growth of renewable energy sources connected to their distribution networks.

The DER penetration rate is increasing significantly and is still expected to grow in a near future. DER integration

with “passive” distribution power systems and open electricity markets raises several technical and regulatory issues.
When generation units are connected to distribution feeders DSO take into account technical constraints related to each generation process and technologies of DER. Different issues are at stake with the advent of DER on distribution networks:

- steady-state and short-circuit current constraints
- power quality
- voltage profile, reactive power, voltage control
- contribution to ancillary services
- stability and capability of DER to withstand disturbances
- protection aspects
- islanding and islanded operation
- system safety

Depending on the country, these issues are dealt with in different ways, since distribution networks may be different for example, in terms of voltage levels, topology and configuration, characteristics, operation and protection philosophy, security regulations, and types of loads. Other factors such as political or socio-economic factors may also play an important role in this field.
A common fact is that the DER is neither visible nor manageable by the Transmission System Operator (TSO). DER replace power capacity traditionally supported by conventional centralized generation, connected and managed by the TSO. In addition, DER can not provide ancillary or system security services, mandatory for the safety of the power systems, which are provided today by conventional generation.
European countries pushed forward with the development of an open electricity market, and thus promoted the development of competition in power generation, including DER. However, the technical constraints of DER connections to distribution systems, the costs of renewable energy (most European countries have agreed on special tariff and conditions for renewable) raise challenges for the complete integration of DER in open electricity markets.

An integrated R&D project called FENIX, which includes utilities, manufacturers, research institutes and academics, included in the 6th Framework Programme of the European Commission, for sustainable energy systems, aims at studying a concept of a “Virtual Power Plant” (VPP) that will enable single DER to be fully integrated into distribution power systems and open electricity markets through coordinated cooperation of DER.
Besides the economic benefit of integrating small generators into electricity markets, FENIX may also offer new services to the grid.
Aggregation of small generators and controllable loads through a VPP may offer competitive and significant energy blocks, and also potential grid management services. coordinated DER units could not only participate in ancillary services (active power reserves for frequency control, reactive power reserve for local voltage control, black starts, etc.) that ensure stability and safety of the power system, but also new power quality, communications or energy businesses services.
A VPP would thus provide valuable support to grid operators, offer new business opportunities and increase competitiveness on electricity markets.
The FENIX project aims to verify the feasibility and value of the VPP concepts, and finally demonstrate prototypes of VPP during 2009.

2/ VIRTUAL POWER PLANTS

A single small generation unit connected to a distribution network cannot offer cost effective capacity, reliability, flexibility and controllability in an open electricity market, or meet the grid code requirements for power systems’security.
A Virtual Power Plant (VPP) is a flexible representation of a portfolio of DER that optimises the economic value of the energy produced, and offers reliability and capacity for ancillary services.
For example, individually, isolated wind generators, reciprocating engines or controllable loads, due to wind forecasting errors or price of fuel are not 100% reliable, and would not wish to participate in the open markets. They could be used in a coordinated way to overcome the variations of wind, and in cooperation they would be able to meet the necessary reliability.
A VPP would aggregate many diverse types of DER, simplify each unit’s technical and economical parameters in order to be characterized in terms of a conventional centralized power plant set of parameters, such as active and reactive power capacity, scheduled generation, ramp rates, price, etc.
A VPP would have to accomplish two main activities, outlining two different roles and responsibilities: a Commercial Virtual Power Plant (CVPP), that elaborates the economical optimisation of a VPP portfolio for the open electricity markets, and a Technical Virtual Power Plant (TVPP) that ensures the power system is operated in an optimised and secured way, taking physical constraints and potential services offered by VPPs into account.

The CVPP contracts power capacity and controllability from a portfolio of DER and controllable loads in exchange of optimised revenues for the generators. The CVPP compiles technical and economical parameters of each DER of the portfolio (technical capacity vs. the marginal costs, wind forecast, etc…) to build a bid/offer ladder to optimise the generators and controllable loads incomes when exposed to the open electricity market. When the markets are cleared and bids and offers are accepted, the CVPP controls the output of its portfolio according to what has been contracted on the market. A CVPP can contract with any number of DER and each DER is free to choose a CVPP or not. This activity can be undertaken by existing actors like energy suppliers, or new market actors.

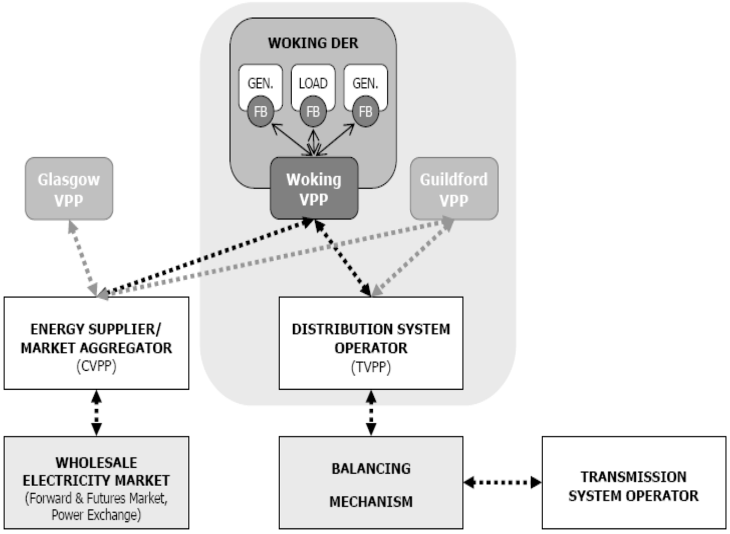
The TVPP would aim to ensure the technical feasibility of the generation program of the DER units and adjustable loads connected to a distribution power system, taking in account the expected work program and potential congestions, and at optimising the contribution to power system ancillary services, originally managed by the TSO. TVPP would receive data from CVPP (generation program, adjustable load schedules, active and reactive capacity, ramp rate, etc…). The TVPP would then optimise the power flows on its power system taking into account the generation units ranked in the "merit order" by the market, the planned work and outages, the active and reactive power capacities from available units, and forecasted load. The TVPP would identify potential congestions that require the removal of a generation unit from the merit order or the dispatch of a new unit, and forward the aggregated results to the TSO. The TSO has the responsibility to balance the power system, now that they have the complete picture of what is available to balance the overall power system and optimise the operational costs.

3/ DISTRIBUTION SYSTEM OPERATOR INNOVATIVE FUNCTIONS

The implementation of the VPP concept requires the TVPP activity to be performed. Indeed, the knowledge of the distribution system (characteristics of the substations, lines and cables, topology and protection schemes), and a recognized unbiased position towards the electricity markets is necessary to achieve the TVPP activity. The DSO is naturally best placed to achieve the TVPP task due to his knowledge of the power systems data, and the regulated nature of its business, the DSO is able to avoid any potential conflict of interest. Thus, the regulatory framework would have to be adapted, and some advanced monitoring and optimal power flow functions would have to be implemented within DSO's control tools.
R&D efforts, related in this paper, were focused on the definition of technical specifications of the TVPP.
These specifications have been defined, based on a use-case approach: "scenarios of usage" of TVPP describe how these innovative functions could be used in the two case studies. These two scenarios are being defined, and will be partially demonstrated in the field. First, the "Northern Scenario" focuses on LV networks in UK, and how the LV distributed generation could participate in system management. Second, the "Southern Scenario" focuses on radial 20kV Spanish networks with a high penetration of DER and how the operators will deal with the generation dispatched by the market, and how they could use that generation to optimise reactive power on their power system.

3-1/ Northern Scenario: British Case

The Northern scenario will be implemented under EDF Energy's supervision and aims to demonstrate a FENIX future in today's environment. It will turn a conceptual approach into physical implementation to show the interactions between all actors involved, from an energy supply business like EDF Energy, a TSO like National Grid, DER owners, aggregators performing the CVPP activity, and DSOs like EDF Energy Networks. It will prove some of the expected CVPP benefits, like the exposure to wholesale electricity markets, and it will help understand the value of TVPP operations in terms of data and DER visibility, for system support and balancing services, energy optimisation and system management in general.



The Northern scenario focuses on Woking in Surrey, which has a high concentration of monitored small scale generation (about 4 MW generated from more than a dozen DER of various technologies, ages, and reliabilities). This generation is connected to low voltage networks, and is linked to a central SCADA system for the data acquisition. Others loads like wind farm or local PV houses may also be integrated in the case. The Northern scenario studies the opportunities to have a CVPP that aggregates these DER and offers the following services:

- participation in the wholesale market, to reduce reliability risk of isolated DER and offer aggregated DER access to energy markets,
- half hourly system management, to offer CVPP an opportunity to bid power offers after the half-hour gate closure for TSO to balance the transmission system,
- frequency response and standing reserve services, to offer the opportunity for long term contracts between TSO and aggregator for power reserve available in predefined time frames.

4-2/ Southern Scenario: Spanish Case

The Southern scenario will be implemented under Iberdrola's supervision and is focused on a typically urban/suburban distribution power system, characterized by a total capacity of around 1200 MVA and a 320 MW peak demand together with 170 MVA DER capacity (small hydro, combined heat and power, wind farms) are connected at the 30 kV or 13,5 kV. The goal of the

Southern scenario is to manage the DER through VPP to provide similar system services as conventional generators. The Southern scenario studies the use of DER through VPP in order to:

- sell large amount of active power on electricity day ahead market, and describe how the TVPP would have to validate the technical feasibility of the generation programs to fit the technical limits of the power system (congestion, voltage, contingencies, etc…);
- provide potential tertiary reserve to the balancing market, and describe how the TVPP would perform optimum power flows in order to define the reserve available at the TSO/DSO delivery point;
- control the voltage and reactive power in order to fit the contracted schedule of power factor taking potential VPP participation to reactive power management;
- support the DSO restoration schemes in emergency situations.

5/ CONCLUSION

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

- can provide services to support effectively the power systems like conventional centralized generation,
- and can improve the revenue of the generators under electricity markets requirements.

Two study-cases, one focusing on Woking's low voltage network with a high level of small scale generation, and the other a Spanish urban/suburban area with high penetration of DER, are studied. This studies identify 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 like advanced monitoring, optimal power flow and real time state estimation that require new data exchanges. It also shows that the UK and Spanish 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 tool to predict and analyse the power system management risks.

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