# DER INTEGRATION UNDER NEW GRID AND MARKET PARADIGMS

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## *ABSTRACT*

*This paper discusses new distribution operation system requirements and challenges in the physical electricity systems going through smart transition and at the electricity market from the aspect of integrated DER with flexible demand.*

## INTRODUCTION

As distributed generation (DG), demand response (DR) and renewable energy resources (RES) become significant portions of overall system installed capacity, a challenge has been put in front of system control centres as well as market regulators in order to cope with the increasing amount of uncertainties being introduced by the new resources, referred to collectively as distributed energy resources (DER).

Although much of the DER emerging under smart grid are targeted at the distribution level, they form important elements for reliable and economic operation of the transmission system and the wholesale markets [1]. This phenomenon is relatively new and regulation is continuously adapting as new issues appear. One case example is fault-ride-through capability at wind power plants that has been promoted in recent years by means of tariff incentives by the Spanish legislation, while the previous normative scenario was requiring exactly the opposite [2].

The real impact of DER in general is still to be discovered because the operational challenges, price mechanisms, incentives, emission targets, fuel prices etc. are directly related to the installation plans. Integrating DER and decreasing problems caused by intermittent DG locally and globally is addressed in this paper with focus on network management point of view and energy market objectives.

## GENERAL FRAMEWORK OF DER INTEGRATION

Architecture of electricity markets in Europe and the perspective adopted by the plan for a massive penetration of DER in the system has a goal of providing access to the wholesale market for decentralized units. Such access can be achieved through aggregation of this production, by connecting each consumer/producer ("prosumer") to a local communications network to ensure two-way communication between the power aggregating agent and clients, enabling the customer to finally access other markets.

From the operation perspective, intermittent generation like wind can cause problems in grids, in physical balances and power quality. Solutions to decrease these problems are to add energy storages into the system, create more flexibility on the supply side to diminish supply irregularities and load variation, and to increase flexibility in electricity consumption. Combining different characteristics of these resources is essential in order to commercially increase the value of DER in the bulk power system and in the energy market. To address these grid and market paradigms, addressing new integration and interoperability requirements as well as identifying systems, functions and operations is of vital importance.

Therefore DER integration framework reflects on four aspects of power system: regulatory vs. operational and physical vs. commercial (Figure 1).

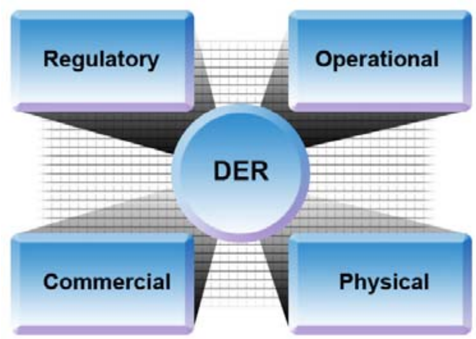


*Figure 1 – DER integration framework aspects*

## NETWORK MANAGEMENT ISSUES

Network management with DER can be best evaluated in terms of the following three aspects: 1) operational planning, 2) distribution system operations and 3) scheduling with system economics.

### Operational planning

DER introduce new constraints in planning optimization procedure. Planning simulations particularly those for demand side management (DSM) are faced with a challenge of having to coordinate many types of different devices amongst such systems: air conditioners and water heaters, storage heaters, home batteries, electrical vehicles, electric space heaters, refrigerators, etc. Such an approach can lead to more complex management and disconnecting more load than expected and unnecessarily affecting a larger group of consumers, or alternatively disconnecting fewer loads than expected that would lead to payment of additional penalties. To prevent these situations, high quality simulation of the expected effects and producing the simulated load diagram are necessary. Qualitative simulation demands detailed data about consumption for controlled devices as well as meter data management (MDM) tools for processing the collected data including distribution management (DMS) off-line tools such as load forecasting.

Additionally, high penetration of DGs in distribution network imposes the need for time setting of relay protection because of unpredictable DG operations that cause more complex relay solutions to be required – like adaptive control and intelligent recloser operation. Tuning the response of protection systems of DG to voltage dips and short interruptions becomes more critical in networks where voltage dips are frequent for example due to network protection based on auto-reclosure sequences. As DGs have influence on network voltage profiles, it makes Voltage/Var control more complex. With an appropriate control of under load tap changing transformers and controlled capacitors, voltage/reactive power profile in the network can be significantly improved [3].

## Impact to distribution system operations

Communications, monitoring, measurement, analysis and information technology links are central to the effectiveness of real-time grid operations, especially in smart grid environment with the integration of diverse resources into power system operations. It can be considered that DER have two-way interactions with the power quality: on one hand many are often rather sensitive to power quality disturbances, because excessive dimensioning is rather expensive and the specification may not have taken into account this potential problem. On the other hand different forms of DGs may disturb the power quality of the network. Thus, the effect of introducing DER in the grid may be positive or negative, depending on whether the infrastructure compensates intelligently for PQ-loss or even aids in increasing power quality. Also automated DR can be used to manage and maintain voltage on feeders, manage frequency as well as responsive reserve to replace lost generation. In general, power quality is usually more important inside the premises of the customer of the distribution company than in the distribution network. Thus the customer, either local generator or user of electricity needs power quality measurement results. Measurements of voltage level, voltage interruptions, and voltage dips are most often needed preferably permanently.

Some types of distributed power production, especially fixed speed wind power plants, have such fluctuations in their output power that cause visually disturbing flicker of incandescent lighting. Measurements of flicker severity indices may be needed in such sites. Distributed power production has often also reactive power compensation that may create a resonance that amplifies harmonics. Faults, blown fuses or unbalanced loads in customer installations or network components may cause incidents that need to be detected rather quickly in order to avoid further damage or tripping protection of DG. Advanced outage management abilities can be facilitated for self-healing ability of the network through DG utilization to resupply important customers in island operation. However, when DER is used as a separate island, also the fundamental frequency needs to be measured for monitoring and control purposes. The short-circuiting behaviour of high DG-RES grids deserves extra attention, because currents flow differently as compared to a completely hierarchical grid.

There is no need to install specific power quality monitoring instruments to a large number of small DER units, although monitoring of the generation is often desired even at small DERs. On the other hand communication infrastructure is necessary for aggregating or coordinated scheduling – e.g. Virtual Power Plants (VPPs).

## DER scheduling and economics

An important goal when integrating DER is that it should, just as every market participant, receive enough payment or compensation to make service profitable. In the traditional and centralized approach, the focus is on the optimizing the operation of the system as a whole with centralized generation and transmission, often neglecting the potential of distributed resources. When more DER are to be integrated, the revenues must also become distributed leading to distributed optimization. Distributed market based optimization does not work well if there is not enough variety in the units to be optimized. Thus a centralized approach is probably often better for the internal optimization of a local system consisting only of a few DER-units [x]. Optimization of the operation of CHP units needs to include storage and use of heat, in addition to electricity and heat production, electricity market and own electricity use. Also the constraints imposed by the power distribution and heat distribution networks need to be taken into account [4]. The actual trading and optimized operation of a DER portfolio or VPP in competitive market conditions is complicated (Figure 2). A large number of factors have to be taken into account: different types of contracts and short-term deals, fluctuations in market prices of electricity and fuels, balancing conditions and suppliers of imbalances, uncertainties related to the consumption and production of electricity and heat, measurements etc.

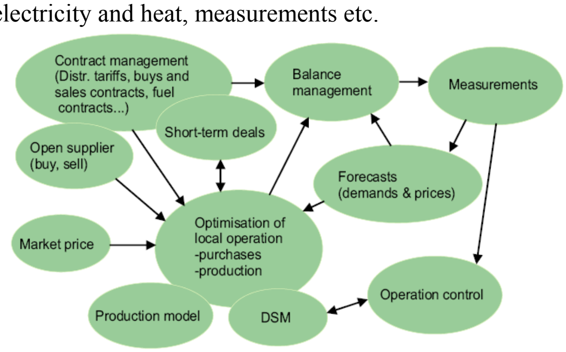


*Figure 2 – DER interconnections for trading and optimized operation*

All these factors affect the optimization of the operation of DER units and on trading of energy and their interconnections are presented in the previous example.

## DISTRIBUTION CONGESTION MANAGEMENT

Congestion management is one of the key issues for secure and reliable system operations in electricity markets. For such operations, the loads of distribution systems are usually treated as aggregated (or projected) loads on the Points of Common Coupling (PCC) in power systems. It is acknowledged that, in some cases, load demand control can be more effective than generation rescheduling to mitigate congestion [5].
If in a distribution system the substation or line capacities are at stake the network operator has to apply load shedding techniques in order to relax the system. The optimal way to avoid distribution congestion is to avoid peak loads. Coordination if DER devices can become an important tool for network operators if their flexibility of operation is utilized in such a way that the demand is shifted to periods with lower demand and supply is shifted to periods with higher demand [5].
With the intelligent DMS software, an example of peak load shaving is enabled by control of automated network field equipment, such as HV/MV tap changers, capacitor banks, switchgear under SCADA control, smart metering, etc., all being included into demand side control. DMS’s functions providing this capability combine network reconfiguration and control of active and reactive power for optimization, reduction of voltage for demand reduction, load management with appliances such as air conditioners or water heaters for peak shaving, and eventually emergency load shedding with disconnection of entire feeders in minimal way [3],[5].

## EXAMPLES OF DER INTEGRATION IMPACT TO NETWORK OPERATION

Several initiatives are helping promote the role of DER under the smart grid and energy market paradigms and they are presented under recent regulatory initiatives in Europe. Related to the congestion management, the first trial field test in the Netherlands with μ-CHP units comprised of a cluster of these units operated as a VPP, demonstrating their ability to reduce the local peak demand of the common low-voltage grid segment the μ-CHP units were connected to. The field test used 10 domestic Stirling based μ-CHP units, $1kW_{el}$ each, at consumer premises. In this way the VPP supported the local distribution network operator (DNO) to defer reinforcements in the grid infrastructure (substations and cables). Although not all μ-CHP units included in the field test were connected to the same low-voltage cable, during the trial a connection to a common substation (i.e. low-voltage to mid-voltage transformer) was assumed. Notably, the field test actually controlled the μ-CHP units at people's homes [6].
There is also a multitude of findings in the recent EU co-funded projects DG-GRID, SOLID-DER, SUSTELNET, MoreMicrogrids, FENIX, DISPOWER, etc. that contribute to acknowledgement and solution of the new grid and market paradigms related to DER integration.

## CONCLUSION

Implementation of DER in active distribution networks of today cuts across several aspects of power systems and impacts different units within distribution companies. DER are an important ingredient of the smart grid, affecting market structure and operational reliability of present as well as the future. A major contribution to the EU objectives towards achieving improved sustainability, security of supply and competitiveness in the energy sector will come from harnessing the potential flexibility in electricity demand and in distributed generation.

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