Scenarios. Visions on global energy systems. Is distributed generation a true game changer?

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Distributed generation (DG) is not a possibility, it is a fact. It is already happening both at the residential and commercial level – mostly as rooftop solar photovoltaic (PV) generation, but also as micro-cogeneration and back-up generation – and it is steadily growing in the form of wind and solar farms that typically connect to medium and high voltage distribution networks all over the world. On a clear and sunny Saturday morning in May 2012, distributed solar PV generation in Germany provided 50% (22 GW) of the electricity demand in the country. Important figures can be also given for the power systems of Denmark, Italy, Spain and the state of Texas, among others.

No doubt large scale wind and solar power plants will require profound reforms regarding how power systems have to be designed and operated, from a reconsideration of the present pricing rules, the gate closure times or the possible appearance or redefinition of the existing ancillary services, to the mechanisms for demand participation. But the intriguing open question that we shall consider here is whether small-scale DG – from rooftop PV panels to residential or small commercial micro-cogenerators to the vast amount of back-up generators in banks, hospitals, commercial centers, hotels or office buildings – will become another game changer and under what conditions this may happen. The first thing to be realized is that the assessment of the future of small-scale DG cannot be decoupled from its integration with demand response and local storage. DG and demand participation will become, and actually have already become, inextricably coupled. DG is obviously very close to end consumption, and in many cases it is, or will be, a single agent, a "prosumer" (from production and consumption), who owns and operates both. In other cases the proximity between DG and local demand is such that it is inevitable to think of the former as supplying the latter. As storage in different formats – including electric vehicles connected to the grid – becomes economically viable at the local level, it will also contribute significantly.

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This close integration of demand, generation and storage resources, all of which are interconnected and physically linked by the electricity network, can be examined from an interpretation of the term micro-grid that

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seems to make more sense than what is frequently encountered in the technical literature (where micro-grid is typically defined as a small power system that is meant to operate mostly autonomously)[2]. Here, we understand a micro-grid as a grid-connected ensemble of demand, energy storage and generation resources with advanced control and communication capabilities, which jointly interacts with the rest of the power system in order to better meet its own economic, reliability and environmental objectives[3].

The essential factor that could transform DG into a true game changer is whether local supply can compete favourably in economic and environmental terms with centralized generation

One can think of a fully decentralized paradigm whereby the global system operators – the transmission system operator, TSO, at the upper bulk system level and the distribution system operator, DSO, at distribution level – define the several commodities to be traded in the electricity market (electric energy, different types of operating reserves, firm capacity, or voltage support) and the corresponding trading times (from multiannual to real time). Moreover, metering and communications are developed so that every single demand appliance, local generator and storage has real time information about the local prices of electricity including any network and other regulated charges, and makes rational economic decisions that, once aggregated, constitute the optimal global response to the predominant power system's technical and economic conditions. This is the straight extension of the current paradigm, where system operators maintain their central role and are in charge of all economic and technical functions on the network side of the end consumer's meter. Consequently, DSOs and large generators and consumers that are directly connected to the transmission network are the only agents that interact with the TSO.

This level of centralization may not be impossible, but the micro-grid paradigm is a possibility that may end-up being the dominant alternative (or, perhaps, some combination of both). Under the micro-grid paradigm, at the individual residential level, some local "energy control box" would be in charge of managing all of the energy appliances, as well as the generation and storage resources, and deciding the best joint utilization given the energy needs of the household and the existing economic and reliability conditions in the power system.

The same approach can be valid for a group of residential units, maybe with some common generation or storage, or a larger aggregation of residential and commercial entities, up to the level of a neighborhood or a small town. All of these would be examples of micro-grids.

The key point is that local management and control probably could make better use of the existing local synergies and use resources closer to the existing constraints, so that the micro-grid manager could get better economic conditions for its members while also providing improved aggregated services with commercial value to the centralized system operator. The magnitude of these potential advantages still remains to be proved.

The essential factor that could transform DG into a true game changer is whether local supply – integrated individually or collectively with demand response, storage and any other resources – can compete favorably in economic and environmental terms with centralized generation. The comparison is not a trivial matter, as many aspects are involved. Obviously the first element to be considered here is the total cost (installation, operation and environmental impact costs) of local generation relative to the total cost of centralized generation, for the

[2] The term "distributed local systems" or DLS could be used instead.

[3] Under extreme conditions, such as locations that are far apart from the main grid (this is frequently the case in some developing countries), micro-grids could be designed to be autonomous. This is of utmost interest in the efforts to achieve universal access to electricity, but this is not the focus of this short note.

different operational regimes that are characteristic of generation plants in power systems. However, other elements are also of essence, and this is where regulation might be a determining enabling factor, as we shall examine next.

For too long already, electricity regulation has been oblivious to the fact that distribution networks are not only used by loads, so that the network charges – which could be credits in some cases – should be shared with local generation sources and (eventually) storage. The design of these charges, the adopted procedure to meter demand and production of a given agent (e.g. net metering versus the use of two separate meters), and the format of the charge – e.g. lump annual sum versus volumetric (in €/kWh) or per capacity (€/kW) charges – can be critical in determining whether DG is economically viable or not in the absence of regulatory subsidies[4].

Local demand and generation, if conveniently aggregated, can deliver different ancillary services with economic value, for instance by partly replacing the operating reserves provided by centralized generators. Local management and control of demand, generation and storage facilities may better address the needs of the end "prosumers".

If this is the case, and the micro-grid paradigm can successfully compete in economic terms and services with the centralized paradigm, then we are facing a true game changer. Different types of these "distributed local systems" will proliferate under a diversity of new business models, some of them developed by the incumbent utilities. "The future will never be what it used to be".

But, it is pointless to try to conjecture what the future will bring to us. Reality always discovers ways that even the best-informed imagination fails to identify. We should expect the unexpected. The priority task in regulation is not to try to predict what the future of DG will be, but to design the regulatory mechanisms and to remove the regulatory barriers that will enable this potential interaction between DG, demand, storage, electricity networks and information and communication (ITC) technologies to flourish, fueled by the imagination of entrepreneurs and the interests and needs of consumers. New approaches to the remuneration of electricity networks that recognize the increasing complexity of these networks and the need for innovation, novel designs of network charges that are adapted to the new uses of the distribution networks, clear identification of the commodities with economic value in electricity markets and facilitation of access to these markets of aggregations of many small agents, and reforms in the rules of wholesale markets to adapt them to strong penetration of intermittent generation and multiple and unusual providers of services – these are the regulatory reforms that can enable the creation of a power sector with as much distributed generation as it merits.

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[4] For instance, net metering, when accompanied by volumetric network charges (i.e., applied in €/kWh), amounts to a subsidy to local distributed generation, who does not pay network costs while the network charges that apply to the local demand are strongly reduced simultaneously.