Active User Participation in Energy Markets Through Activation of Distributed Energy Resources

J. Driesen, *Member, IEEE,* G. Deconinck, *Member, IEEE,*
W. D'haeseleer *and* R. Belmans, *Fellow, IEEE*

***Abstract* — Customers in liberalized energy markets do not have tools in hand to contribute to the balancing of undispatchable distributed generation and the uncontrolled loads. This paper discusses how an activation of the loads could make users more involved in energy markets and indirectly support the sustainable deployment of distributed generation often based on locally available renewable energy sources. As such, a contribution is made to the security of supply through a larger resource diversification and the smaller customers may be engaged in delivering certain types of ancillary services such as reserve provision.**

***Index Terms*-- Distributed generation, distributed energy resources, energy markets, liberalization, active loads, demand-side participation.**

I. Introduction

THE liberalization of the energy markets is starting to take off in Europe: EU legislation states that there should be competition in generation and retail markets upon January 1, 2007. At the same time, sustainable electricity generation is heavily supported bringing along many GWs of installed generation units mainly based on wind power. In a similar way many gas-driven CHP units are being installed.

Locally built, distributed generation (DG) [1-4] may at first sight be a useful technology to function in an open market as it gives users the opportunity to fill in part of the local demand often using locally available sustainable resources ('power to the people') and shop around for the remaining bits, perhaps even selling excess generation. This idealistic picture is not what is seen in practice: DG is experienced as a nuisance by the grid operators requiring a relatively large effort in grid adaptation and ancillary services, for instance in balancing [5].

An underlying problem is that the users hosting local generation do not have the full technical capability to participate in the energy market and grid support yet. At this moment, it is practically impossible to perform a local form of balancing between local generation, an occasional form of energy storage and the dynamically changing loads. All three are forms of DER: 'distributed energy resources', in which the latter, the loads, currently are almost completely passive and therefore, cannot benefit from energy market opportunities translated into price signals.

This paper discusses the difficulties and opportunities for activated loads to function in a system with significant amounts local generation.

II. The energy market and DER

A. The user's stake in the energy market

A good working market requires active suppliers and an active demand side. The latter lacks in energy markets. Communication between supply and demand is organized unidirectionally, which makes it impossible for the customer to really take part in the market. The customer presently receives no real-time price information or indications on the origin of the electricity, other than difficult to understand, very general tariff systems. These do not really offer any insight in the relation demand-price and therefore, do not provide any incentives to change his/her demand according to market fundamentals.

In fact, the benefits of energy liberalization will only come true if the demand side gets activated as well. At the same time security of supply has to be ensured at all times and environmental concerns are rising. The demand side, complemented with local generation, can also affect both aspects. Small energy users have potential to increase energy efficiency and to contribute in clean electric energy generation. An active demand side opens opportunities in providing capacity to the market and local generation, if correctly operated, can increase reliability.

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J.Driesen, G.Deconinck and R.Belmans are professors of the Katholieke Universiteit Leuven, Department of Electrical Engineering, research group ELECTA, Kasteelpark Arenberg 10, BE-3001 Leuven, Belgium (e-mail: johan.driesen@esat.kuleuven.be, geert.deconinck@esat.kuleuven.be, ronnie.belmans@esat.kuleuven.be; http://www.esat.kuleuven.be/electa). W.D'haeseleer is professor in the Mechanical Engineering Department, research group TME, Celestijnenlaan 300A, BE-3001 Leuven, Belgium (e-mail: william.dhaeseleer@mech.kuleuven.be, http://www.mech.kuleuven.be/tme).

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However, the way in which energy at small user level (individuals and small business and services) is treated today does not meet current challenges and policy incentives. Energy efficiency is not fully rewarded. Today's energy system offers customers hardly any flexibility. The system is, in practice, not easily accessible for local generation technologies. At a local level, consumers have no possibilities to arbitrate between different energy sources available. Electricity, natural gas and local, often renewable generation are treated separately. Activating households and other small energy users will enhance sustainability, increase efficiency and result in economic value.

B. *DG in the market*

Distributed generation is a technology that received widespread attention in the past years. Some technologies have proven to be successful, but can only survive without lots of direct and indirect support in a liberalized market. This is discussed through the three perhaps most popular DG types: wind power, photovoltaic conversion and combined heat and power (CHP) [4-6]. Note that storage is not discussed separately, but rather seen as a complementary technology that may smooth out irregularities in generation and consumption.

1) *Wind power in the market*

In the past ten years many GWs of wind power have been built in Europe (mainly Denmark, Germany, Spain and the Netherlands), the US and other parts of the world follow. Usually, wind power is given a financial benefit through e.g. installation subsidies or tax advantages, 'green energy' certificates functioning in a retail portfolio obligation, grid access priorities or lowered balancing costs. This in fact cannot help that wind power has a fundamental handicap of being hard to predict on longer times scales as encountered in markets, for instance a market with a 24 hour gate closure periodicity. Wind power would most likely become much more interesting in markets with shorter gate closure times such one hour, converging to real-time markets. Alternatively, wind power would benefit significantly from the availability of easily accessible reserve power or storage, regardless of the form in which it is implemented.

2) *Photovoltaics*

Pholtovoltaic (PV) generation suffers from similar problems as wind power, be it rather on distribution than on transmission grid scales. It is to be integrated with existing (radial) distribution grids, next to loads having cycles that are entirely uncorrelated with the solar cycle. This causes local balancing inequalities eventually resulting in large voltage changes and protection (selectivity) problems when bidirectional flows occur.

3) *CHP*

CHP fundamentally is a heat demand driven generation of electricity, as a by-product. There is the option to include thermal buffering, but this is in general not designed with a smooth electricity generation cycle in mind, yet. CHP in fact links two markets: the primary resource markets which normally is natural gas and the electricity market, but these are usually not approached in parallel.

C. *The reliability paradox*

Questions are raised about the difficulties linked to further deployment of certain types of DG as discussed in many papers. Grid reinforcements are required and some operational practices need to be fundamentally reconsidered. On the economic side, the market is distorted or overly complicated by the presence of certain types of DG [5].

Moreover, one can state that a "Reliability Paradox" has emerged: the addition of generation based on energy hard to ignore opportunities, has made the electricity system, in urgent need of extra generation after an investment slowdown induced by the start of the liberalization process, even more insecure.

D. *Demand control as a solution?*

Seldomly suggestions other than slowing down the deployment of DG are suggested. Until now, mainly DG and its problems were discussed. However, a solution may be found in looking at all types of DER, more in particular, the resources represented by the loads (note that the IEA definition of DER includes DG, storage and active loads [1]).

A technology allowing to shed or modulate some load locally on a small-scale following generalized price signals, indicated as 'active' loads, contributes to the solution of the balancing problem. As an example, one can imagine a fridge being able to shift its off-take of electricity to cool in time following price signals as control variable. Considering that on average every household owns at least one fridge and the number of households, which is about equal to the number of house connections (equal to about 50-75% of the population of a country), this quickly becomes an important 'spinning reserve' for the local as well as for the global electricity system. This 'spinning' reserve can be addressed when there is a local overload on the distribution feeder as much as to contribute to a smoother load shedding in case of contingencies.

As such demand control impacts the security, adequacy and stability of supply in multiple senses:

- it allows to better utilize local energy opportunities replacing imported resources and therefore enhances the resource diversification (security of supply);
- it offers additional ancillary services for the system

operators in the form of, mainly, (negative) reserve power that can be used in the primary/secondary system control (adequacy and stability).

Therefore, demand control may in the future become an important enabler for the further deployment of distributed generation systems. However, two steps have to be taken in the development of the local energy control. First of all the concept of the required energy controllers needs to be detailed, including their hardware, control and communication. It also turns out that a multi-energy or multi-resource approach is necessary, explained in the next section for the perspective of the users.

III. INCREASED ENERGY MARKET PARTICIPATION

A. *Towards efficient and flexible small energy users*

From a theoretical perspective, an optimal use of market forces and the price mechanism can strongly improve the efficiency of the whole energy system [7]. These efficiencies are not limited to increased consumer and supplier surpluses but can also include technological dynamics [8].

Adopting a user-centric approach (Fig.1) makes it possible to combine all elements determining the energy use of households and small energy users. Focusing on the user enables to evaluate how users are affected by different technologies. Even more important, this view gives the opportunity to see how technologies can interact and how they can create value for the user. For instance, from a user point of view the integration of electricity, gas, local generation, demand side control (time shift for instance), mobility and local storage opens opportunities to arbitrage between these energy sources and to interact with energy markets. This does not only result in local benefits; society as a whole can gain from it.

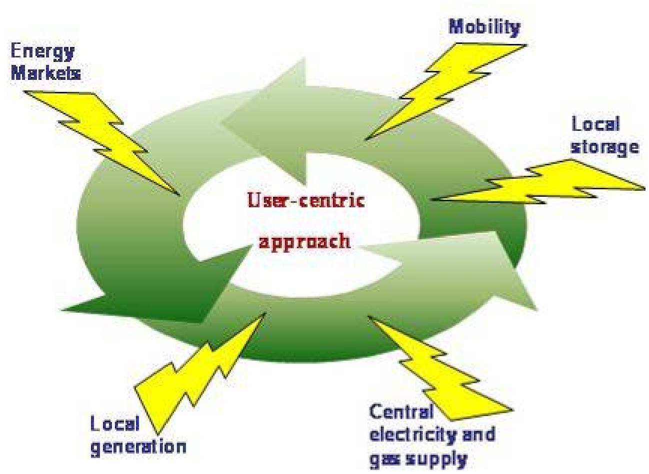

Fig.1 Interaction in a user-centric approach.

More efficient and flexible small users who also implement local generation technologies can help improving overall energy efficiency and increase security and adequacy of the energy system. By installing local generation based on renewable energy sources, sustainability can be improved. A last but important element is user well-being. A user-centric approach allows incorporating user comfort in the analysis. Maintaining and when possible even increasing the current level is an important constraint when such a technology has to be accepted by the public.

B. *Technology*

A real breakthrough of retail markets can only be initiated by active metering tools. By improving both internal and external communication with market players and devices, a better measuring of relevant data is possible. An intelligent system has to be developed to organize control and interaction, as transparently as possible. The use of real-time prices and information will be crucial. However, the economical feasibility remains to be investigated.

C. *Link to mobility*

On the electricity demand side, plug-in hybrid cars can also be considered an option for efficient energy use. Plug-in hybrid electric vehicles (PHEV) are the next phase in the evolution of hybrid and electric vehicles. Hybrid electric vehicles combine a conventional internal combustion engine (powered by gasoline, diesel or biofuel) and electric motors. There are several engine architectures possible and the size of the internal combustion engines and the electric motor differs. The fuel efficiency of this vehicle is better than that of conventional drive systems, and the batteries can be charged using electric energy from the distribution grid or through on-board electricity generation [9].

Since PHEVs can be controlled in their charging process quite easily, they form an excellent candidate for a controllable load. In theory, their on-board power reserve (and even generation capacity) could be addressed to inject power in the grid.

D. *Multi-energy approach*

In order to capture the larger-scale consequences of DG implementation or load activation, the natural gas and electricity networks and the off-take profiles have to be considered in parallel as overlaid networks. This is important as a change for the good in one system may have adverse effect in another, for instance: massive use of gas-based CHP may lift some stress of the electricity transmission system, but will most certainly lead to congestion of the gas distribution. An investigation of the parameters driving the profiles provides information about how they can be influenced accounting for the impact of local, renewable energy sources (Fig. 2). Eventually the three resources have to be distinguished: electricity, natural gas and renewables in a broad sense.

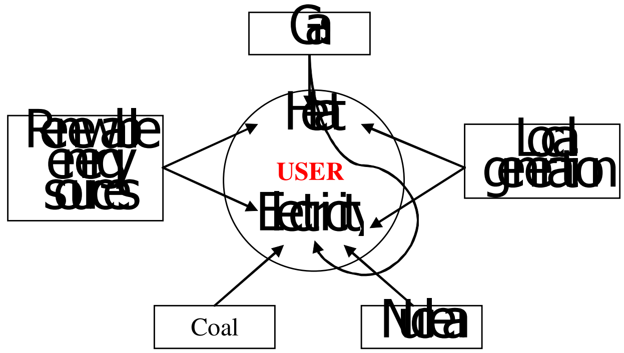

Fig.2. Multi-energy resource interactions.

IV. Conclusions

The activation of electrical loads with small users, the so-called demand-side participation, helps the further deployment of sustainable types of distributed generation such as wind power, PV and CHP through a contribution to balancing locally as well as globally. As such it represents a contribution to the security, adequacy and stability of supply through the enlarged diversification of primary energy resources and the creation of necessary ancillary services, more in particular reserve provision. Unlike a blunt introduction of DG, a combined introduction of both types of DER, DG and complementary demand control may help to solve the 'reliability paradox'.

Obviously, further research is required into the technological implementation of demand control. A new class of active metering devices is required. Their communication and distributed control algorithms form a challenge. These devices have to consider all energy resources relevant for the small users, in practice electricity and natural gas. Additionally the exact estimation of the economically feasible demand control potential in realistic circumstances will be a difficult task for the future.

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VI. Biographies

Johan Driesen (S'93–M'97) was born in 1973 in Belgium. He received the M.Sc. degree in 1996 as Electrotechnical Engineer from the K.U. Leuven, Belgium. He received the Ph.D. degree in Electrical Engineering at K.U.Leuven in 2000 on the finite element solution of coupled thermal-electromagnetic problems and related applications in electrical machines and drives, microsystems and power quality issues. Currently he is an associate professor at the K.U.Leuven and teaches power electronics and drives. In 2000-2001 he was a visiting researcher in the Imperial College of Science, Technology and Medicine, London, UK. In 2002 he was working at the University of California, Berkeley, USA. Currently he conducts research on distributed generation, including renewable energy systems, power electronics and its applications, for instance in drives and power quality.

Ronnie Belmans (S'77-M'84-SM'89-Fellow '04) received the M.S. degree in electrical engineering in 1979, the Ph.D. in 1984, and the Special Doctorate in 1989 from the K.U.Leuven, Belgium and the Habilitierung from the RWTH, Aachen, Germany, in 1993.

Currently, he is full professor with K.U.Leuven, teaching electrical machines and variable speed drives. He is appointed visiting professor at Imperial College in London. He is also President of UIE.

He was with the Laboratory for Electrical Machines of the RWTH, Aachen, Germany (Von Humboldt Fellow, Oct.'88-Sept.'89). Oct.'89-Sept.'90, he was visiting associate professor at Mc Master University, Hamilton, Ont., Canada. During the academic year 1995-1996 he occupied the Chair at the London University, offered by the Anglo-Belgian Society. Dr.Belmans is a fellow of the IEE (United Kingdom). He is the chairman of the board of Elia, the Belgian transmission grid operator.