THE INTRODUCTION OF LOCAL SYSTEM SERVICES: THE CASE OF STORAGE IN THE LOW VOLTAGE NETWORK

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ABSTRACT

Socio-economic trends are thought to cause a significant change in the dominant type of electricity supply and consumption. The current operation of system services might become insufficient. In this work local system services (LSS), defined as actions performed at a local level to contribute to the technical and financial stability of the system, are studied as a possible solution. Adaptations of the tariff systems will be needed, but legislation offers possibilities to implement these changes.

INTRODUCTION

Socio-economic trends are thought to cause a significant change in the dominant type of electricity supply and consumption. Demand from the distribution grid will change due to a possible higher application of electric heat pumps and electric cars, while the current dominant way of electricity production will be replaced by renewable energy sources. The distribution level of the electricity system is influenced by the increased application of PV panels and micro-CHPs and the new forms of load. These changes in the electricity market will have two major effects on the functioning of the electricity supply system. First, the either very intermittent and/or inflexible behaviour of the new electricity generators will cause a higher amount of unbalance in the system, since these types of generation will hardly be able to match demand at all times, leading to high unbalance costs. Second, local congestion will occur more often due to the increasing demand of electricity in cases of the application of electric heating and transport. This means that the current operation of system services might become insufficient and a solution is needed.
In this work local system services (LSS) as a possible solution for this problem have been studied. LSS use locally available flexibility to supply services needed for system stability. The LSS are discussed regarding institutional barriers for implementation; they also have been simulated using storage in the low voltage network.

FITTING LOCAL SYSTEM SERVICES IN THE MARKET

Local system services

System services aim to secure the transport of electricity, deal with disturbances and maintain or restore balance [1], or facilitate the free market by offering trading opportunities [2]. Currently, system services are provided by large, central players being the transmission system operator (TSO) and large producers. However, certain system services could also be performed by smaller units at the low voltage level. Due to their location these suppliers are well suited for the provision of “for local” system services, including voltage control and local congestion alleviation. Combined these suppliers can influence system balance and might also enter the high value system services markets. In this paper local system services are defined as actions performed at a local level aimed to contribute to the technical and financial stability of the system. Table 1 gives examples of LSS suppliers and table 2 possible LSS.
Note that for ‘local for local’ the location of the LSS supplying devices is important. For ‘local for global’, a large number of devices is needed and an effective control.

Table 1. Examples of suppliers of local system services

Type	**Examples**
Controllable generator	Micro-CHP, …
Flexible load	Electric car, washing machine, …
Device with inverter based control	PV systems, drives, …
Storage	Li-on battery pack, heat storage in combination with heat pump, …

Table 2. Possible local system services

Local for local	**Local for global**
Voltage control Network alleviation Island or micro grid operation Right-through capability Local balance control	Provide unbalance power Reduce installed generation capacity Reduce network losses Improve network efficiency Contribute to global balance control

Actor wishes and behaviour regarding LSS

In the Netherlands the main actors in the electricity market are consumers, producers, suppliers, TSO, distribution network operators (DNO), the regulator and balance responsible parties (BRP). The possible impact of LSS is summarised in table 3. The introduction of LSS may give opportunities to new actors, e.g. service companies, with tasks such as solving unbalance and/or congestion problems, protecting or helping consumers with price volatility and power quality services.

Table 3. Possible impact of LSS for different actors

Actor	Possible impact of LSS
Consumer	Cheaper energy in exchange of flexibility, privacy issues
TSO	More complexity
DNO	May offer additional services (DNO → DSO (distribution system operator))
BRP	Local balance control might assist global balance
Supplier	As contact to consumer: new contracts
Regulator	New legislation
Service company	*May offer services (buying/ selling energy, selling flexibility, …)*

Barriers for the implementation of LSS

In the Netherlands the responsibilities regarding system services can be found in the system code [3] and the network code [4]. The following requirements apply for suppliers of system services: minimum of 5 MW unbalance power, 100% availability, direct control by the TSO, and registration and bidding needed at the TSO level. Individual households are ruled out since they are unable to provide 5 MW power.

In the tariff structure for the DSO some limitations occur as well since the current tariff structure does not have the possibility of paying consumers for their contribution to system services. On the other hand regulation prescribes that the network operators together can propose to change the tariff structure and include the possibility for system services. Two limitations on this tariff will remain: the benefits the DSO can offer are limited (since total service costs are limited) and the DSO is not allowed to discriminate regarding tariff structure based on location or distance to the network point of coupling.

Besides the legislative barriers, main barriers are the established routines in the electricity market, which are difficult to change. The main actors in the current electricity market have no direct need for LSS. Costs of changing to a different way of operating the system services may be too high. It is also uncertain how the TSO will respond, as the introduction of LLS will create more complexity in the system and consequently more monitoring and measuring will be needed.

There are also technical challenges since the implementation of LSS needs effective, reliable and secured control and communication.

Possible solutions for the implementation of LSS

In literature the following options are given for the supply of LSS, mainly based on demand side management [5]: direct load control, time-of-use tariffs, critical peak pricing, real time pricing, demand side bidding, power reduction, profile contracts, micro grid with internal market. A global distinction in these options can be made in the method of control: direct control by the buyer of system services versus control by the supplier based on stimulation (price) signals from the buyer. A second dimension is the physical location of the suppliers of system services, either it is within the houses, meaning consumers will supply the services or it concerns a larger production or consumption unit owned by a commercial or regulated party.

Concerning the needed information exchange, the smart meter could already overcome a major part of the problems. Internet connections or communication through electricity lines could be sufficient for the data transmission. However the suitability of internet for local system service control should be subject of further research with regard to the reliability of the connection and the safeguarding of consumer privacy.

CASE STUDY: LOCAL SYSTEM SERVICES USING LOCALLY AVAILABLE STORAGE

Introduction

In a case study the application of LSS in a residential area for local congestion management and balance keeping is studied. Storage technology is chosen to deliver LSS, because it is regarded as a promising new technology with little intrusion on the consumer's current comfort. Storage is expensive, but is thought to become more feasible with increasing technological development and more application areas. Table 4 gives possible control strategies for different location and control dimension of the storage. Only the strategies in which the storage can address several markets or fulfil several system services will be studied further.

Table 4. Possible control strategies of storage in a residential area

Place storage + Control level	Control strategy (+ name control scheme in simulations)
Placed and controlled in every house	Difference in tariffs: day-night, feed-in – extraction,… (not simulated)
	Household responds on signal sent by integrating party if beneficial (in simulations: **houses, price**)
Placed in every house, central control	Energy price (APX) driven (not simulated)
	Service driven (in simulations: **houses, direct**)
Centrally placed (substation), central control	DSO control – offering system services as cheap as possible (in simulations: **central, direct**)
	Commercial control, responds on financial stimuli (in simulations: **central, price**)

Institutional embedding

Table 5 summarises actor tasks and responsibilities for the studied storage control strategies for LSS.

Table 5. Actor tasks and responsibilities for LSS

Control scheme	Consumer	DNO	BRP	Regulator
Houses, direct	- Own storage - Allow control	- Send network signal - Measure response	Send BRP signal	Allow tariff change
Houses, price	- Own storage - Set price threshold	- Send network signal - Measure response	Send BRP signal	Allow tariff change
Central, direct	(none)	Own storage	Send BRP signal	Allow storage ownership by DNO
Central, price	(none)	Send congestion signal	Own storage	(none)

Technical aspects - simulations

Simulations have been performed for a hypothetical, but representative Dutch residential area, with 180 houses, 3 flats, 1 school and 1 shopping centre. The LV network is radial (cables: Al, 95 mm^2), with ca. 40 houses per feeder and utilities on a separate feeder, connected to MV grid by a 630 kVA 10kV/400V transformer. Loads (power demand of households, electric car, heat pump), µCHPs and PV systems are modelled based on load and generator power profiles [6,7]. The storage device(s) (1 kW- 4 kWh per house) react on congestion signals (based on transformer loading), unbalance [1] and energy price [2] by injecting (if battery not empty) or consuming power (if battery not full) (fig.1). In case of direct control, transformer load and unbalance are compared with reference values and the deviations are converted to an aggregate direct (-1/0/1) signal for the storage controller. In case of price based control, a price is put on transformer load and unbalance, which is added on the energy price to obtain the price based stimulus signal. Fig.2 and fig.3 show the response of a storage unit on a direct signal and a price based stimulus signal respectively.

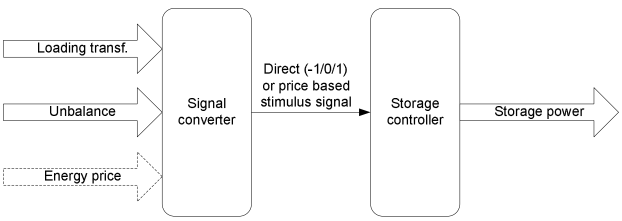

Figure 1. Control of storage device: (dis)charging as a function of transformer (over)load, unbalance and energy price (only in case of price based control)

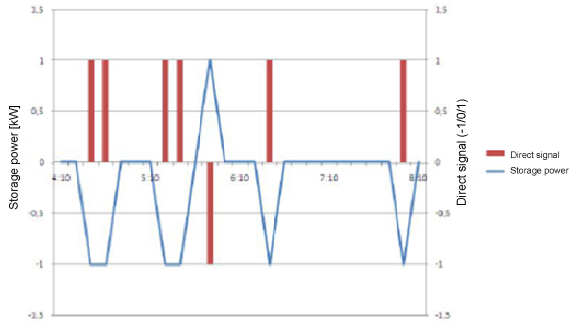

Figure 2. Response of a storage unit on a direct signal (1: discharge, -1: charge, 0: no reaction).

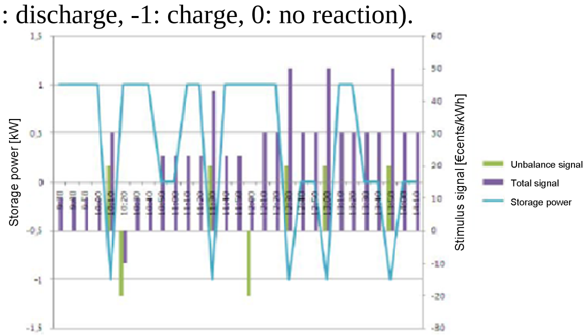

Figure 3. Response of a storage unit on a price based stimulus signal (Low price: charge; high price: discharge; medium price: no reaction)

The four storage control strategies from table 5 are simulated for three configurations: 1) electric heat pump (eHP) and electric car for each house, 2) electric car and PV for each house, 3) µCHP, electric heat pump, electric car and PV for 50% of houses (mixture configuration). Fig.4 and fig.5 show some simulation results of impact of control strategy on transformer loading. Table 6 gives the yearly transformer overloading duration for the 12 cases.

Discussion

The simulations show beneficial effects on transformer loading (table 6). Residential storage has the advantage of being able to reduce losses and loading within the low voltage network and positively influence the voltage at the connections, but the disadvantage of less certain response to control signals and higher costs.

Distribution networks with a high degree of utilisation (e.g. considered eHP+ E-car) are less suitable for providing LSS. The reaction of the storage on the unbalance signal causes extra peaks in the transformer loading (fig.4, fig.5). This might cause short periods of transformer overloading. A possible way to counter this overloading due to local unbalance is to increase or prioritize the congestion signal. Interference between market and congestion signals reduces the responsiveness of the storage units. In general the response of the storage systems is lower when price based control is applied since the APX signal causes extra interference in the control of the signal. On the other hand, price signals induce peak shaving (fig.5).

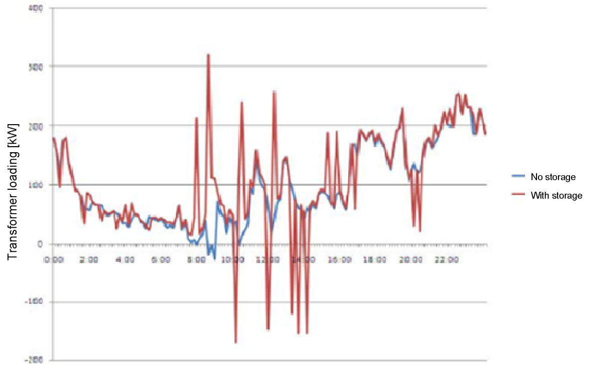

Figure 4.Impact of residential storage with direct control on transformer loading (total power exchange with MV grid) (mixture configuration, winter day)

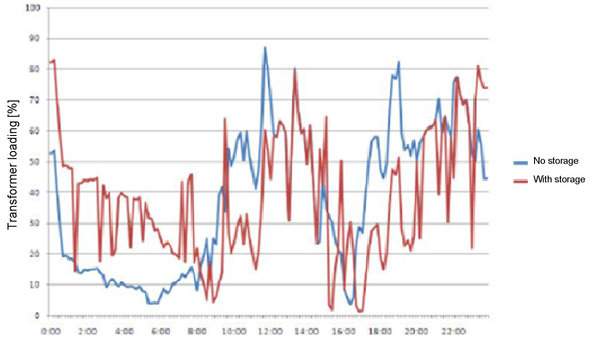

Figure 5. Impact of residential storage with price based stimuli control on tranformer loading (E-car + PV configuration, summer day)

Table 6. Transformer overloading (hours/year) for different cases of storage control and configurations of load/ distributed generation in the residential area

	eHP + E-car	E- car + PV	Mixture
No control	1030 hours	17 hours	0 hours
Houses, direct	650 hours	0 hours	0 hours
Houses, price	630 hours	7 hours	0 hours
Central, direct	930 hours	26 hours	0 hours
Central, price	930 hours	9 hours	0 hours

CONCLUSIONS

In this work LSS are defined as actions performed at a local level to contribute to the technical and financial stability of the electricity system. LSS are an ideal candidate for 'local services', of which the need is also expected to increase. Using LSS for global system stability is less obvious. The main advantage of fulfilling global system services is the possible access to high value markets. Analysis of the current electricity regime shows that little resistance exists to LSS, especially since no privacy issues seem to arise using the proposed control strategies. However there seems to be no direct need for implementing LSS and there is a lack of incentives for network operators to implement LSS. The detailed guidelines on the provision of system services are a barrier for the introduction of LSS, as it requires a minimum size and has strict demands on availability. Legislation prevents network operators to fully enter the system service market as they are prohibited to enter trade. But they can influence the low voltage connection with the aim of congestion relief. Adaptations of the tariff systems will be needed, but legislation offers possibilities to implement these changes. It is also uncertain how the TSO will respond, as the introduction of LSS will create more complexity in the system and consequently more monitoring and measuring will be needed.

In a case study the application of LSS, delivered by storage in a residential area, for local congestion management and balance keeping is studied. The simulations show beneficial effects on transformer loading, voltage profiles and losses within the low voltage network, meaning local storage could have a role for that application (if economically feasible, which is currently not the case). Interference between market and congestion signals reduces the responsiveness of the storage units, decreasing the value of the services. The responsiveness should be improved by a more complex control strategy, that is able to predict signals and to adapt response to different signals. Furthermore the analysis showed that distribution networks with a high degree of utilisation are less suitable for providing LSS because less bandwidth is available for peak loads.

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