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Parallel feed-in grids for renewable energy: Contesting the natural monopoly?

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Abstract

The business of electricity distribution system operators (DSOs) is widely accepted as a natural monopoly and can therefore not efficiently be subject to competition, but needs to be regulated. Regulation comprises the provision of network access and pricing of network usage as well as rules on the operation and reinforcement of the network. In the current paper, the relationship between the DSO and distributed energy resources (DER) is discussed under different regulatory regimes and their economic interests are contrasted. Necessary grid infrastructure investment may only take place according to tight regulatory rules demanding low-cost grid options, and this can cause delays in the erection of DER units. However, DER investors may not find it beneficial to either wait for reinforcement under these conditions or accept severe curtailment. Instead, they might prefer to erect an own network that is not exposed to the same regulatory constraints as the DSO network. This leads to the paradoxical situation of parallel electricity lines at same voltage levels. A parallel feed-in grid that collects power from various DER units in a region and matches this setting has been established in Germany. The objective of this paper is to assess such a parallel network: it gives a brief introduction of the economic and technical background of establishing a parallel network and discusses regulatory implications, especially considering the fact that electricity grids are commonly regarded as a natural monopoly. It addresses the different stakeholders' perspectives and interests and explains which solutions could be implemented, in spite of that they were not explicitly foreseen under current regulation. This is found to be partially due to different temporal priorities in planning, but also due to regulatory flaws. Finally, it is argued whether a further diffusion of feed-in grids is desirable from a socio-economic perspective and how their benefits could be implemented within the existing regulation without the construction of a parallel network.

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1 Introduction

Electricity production from distributed energy resources (DER) is a key element to attain the EU's three energy policy objectives of sustainability, competitiveness and security of supply. A pivotal element of DER is the question how to connect single DER units most efficiently to the rest of the electricity system. In regions with low penetration rates of DER, units can be connected to the existing distribution network without requiring a considerable adaption of the network. In contrast, in regions with a large penetration of DER, this can lead to a demand for reinforcement for both the distribution and transmission grids. Furthermore, the effects of more DER units depend on the management approach pursued by the DSO (cf. Jansen et al., 2007 and Joode et al., 2007). The coordination of intermittent DER units with controllable DER generation or storage options can reduce this reinforcement demand. Current discussions focus on the integration of these options and demand-side management, e.g. in microgrids (cf. Abu-Sharkh et al., 2006). Another option is the bundling of numerous DER units in a coordinated power plant; this requires the connection of the respective units with a power network. This paper offers a discussion whether this should be done in an integrated way in the public distribution grid or separately in a local parallel private network, as is recently practised in a case in Germany. Such a constellation implicitly challenges the common assumption that an electricity distribution grid is a natural monopoly. The presented paper addresses this issue as well as alternative cases and their economic consequences for the individual stakeholders. The paper is structured as follows: the market actors' roles and natural monopoly characteristics are addressed in a first step, and next the concept of a feed-in grid for DER generation is explained. Then, the single actor's interests in this concept are highlighted. Cost allocation and long-term implications are assessed as results, before turning to the discussion and conclusion of the presented arguments and considerations.

2 The setting: Market actors' roles

2.1 Electricity transmission as a natural monopoly

In the last years, competition has been introduced in most parts of the electricity value chain, that is, in generation and supply. Transmission and distribution networks, however, remain to be considered natural monopolies that are characterised by the fact that costs are sub-additive, i.e., that one firm can produce a certain good at lower costs than two or more firms for the known demand of the good (cf. Joskow, 2006). This lack of possible competition causes the need for regulation. As other parts of the electricity value chain are highly dependent on their access to the grid and the operation of the grid, the monopolistic network operators are regulated. Regulation can be sub-divided into several topics:

- Network access regulation ensures the non-discriminatory access of consumers and generators. This part also addresses the question whether DER operators need only to pay for the connection to the closest network point (shallow connection charges) or as well for network reinforcements (deep connection charges).

- Economic network regulation determines the overall revenue and/or its allocation among customer and generator groups. There can be possibilities for discrimination between consumers, generators, and different consumer groups. A network operator's attitude to network reinforcement expenses depends strongly on its economic regulation: it will prefer a higher capital base under rate-of-return regulation or be indifferent if it can recover all expenses under an incentive regulation, but might be hesitant if this is doubtful under an incentive regulation with stronger requirements for cost savings.

- Ownership regulation addresses the question of vertical integration, i.e., to what extent the DSO needs to be separated from other parts of the same owner.

2.2 Distribution System Operator

The DSO is holding the electricity transmission monopoly at the lower voltage levels. More precisely, its task is to operate and ensure the maintenance of the low, medium and high-voltage distribution grid through which electricity is delivered to the final customers. The development of interconnections to neighbouring systems and the "long-term ability of the system to meet reasonable demand" (2003/54/EC) are also at the heart of the DSO's responsibilities. When planning the network development, the DSO shall, among others, take distributed generation into account if this might supplant the need for investment.

2.3 Transmission System Operator

The basic TSO's tasks are analogous to the DSO's, but at the high and extra-high voltage level. Additionally, the TSO is responsible for the stability of the system and the interconnector coordination to adjacent TSO regions. Dispatching and balancing have to be transparent, non-discriminatory and cost-reflective. If market actors deviate from their power input or output plans, they pay commonly for the resulting balancing cost. All other costs - system operation, maintenance and the extension and strengthening of the network - are recurred among the network users. This can be done via connection charges for additionally connected units or use-of-system charges as a variable tariff for network usage. A more in-depth classification and discussion of these issues can be found in Ropenus et al. (2009).

2.4 Distributed generation

There is a multitude of different definitions for distributed generation which apply criteria as purpose, technology or location, i.e. connection to the distribution network (see Ackermann et al., 2001). The latter approach has also been adopted in the current EU Directive 2003/54/EC: "'distributed generation' means generation plants connected to the distribution system." This definition may be helpful for an ex-post judgment and accounting of electricity generation from distributed generation, but does not support the question discussed in this paper: under what conditions are several small, geographically dispersed generation units connected to the distribution grid or to a parallel feed-in grid? For this reason, an altered definition will be applied for the following argumentation: *Distributed generation comprises electric power sources which can be connected to the distribution grid due to their capacity and geographical dispersion.* For the sake of completeness, it should be mentioned that this covers also generation units which are installed at the customer side of the meter (cf. Ackermann et al., 2001). In practice, the definition covers power generation technologies such as wind, biomass, biogas, photovoltaic, small combined heat and power (CHP) units as well as small-scale power storage facilities.

2.5 Customers

Final customers are a heterogeneous group of customers from different sectors, e.g., residential, commercial and industrial. Common characteristics are that the lack of real-time metering causes a lack of demand responsiveness and that power flows cannot be attributed to single customers (cf. Stoft, 2002). Single actors may exhibit a preference for energy from renewable energy resources only and thus, have a higher priority for such electricity products. All customers, regardless whether they buy a combination of conventional and green or green electricity only, have a common interest in obtaining their product as cheap as possible. The overall regulatory constellation should still be designed in a way that customers are not charged more than necessary. This paper's focus is on the interaction of DER support schemes and network regulation, i.e. if these are designed in a concise manner to achieve the least-cost goal and how feed-in grids for renewable energy can be categorised within them.

3 Concept of the feed-in grid for renewable energy

3.1 Definition

The basic idea of a feed-in grid is to connect various DER units from a region not directly with the DSO grid, but with a parallel grid exclusively for the collection of DER electricity. The generation can be collected and transformed directly into the transmission system operator (TSO) grid, bypassing the DSO network. Figure 1 illustrates the two alternative scenarios (based on Schwarz et al., 2008, p. 35). Another feature of the combination of the feed-in grid and all connected generation units is that the different units can be coordinated. Due to the variability of different DER sources, these can partially balance each other. Further benefits of steadying the generation profile can be withdrawn from energy storage units or controllable intermittent resources (cf. Enertrag, undated). The main difference to a virtual power plant, where such units are coordinated as well, is that all units in the feed-in grid are physically interconnected and deliver their generation at a higher voltage level. The core of the analysis is therefore on the ownership of the grid between the generation units and the TSO grid: it can either integrally use the DSO grid or belong to the sum of DER units. In the following, it will be assumed that all the DER units connected to the feed-in grid and the feed-in grid itself are property of the same legal entity. As this feed-in grid operator does not engage in supplying customers with electricity, it is not bound by the same regulatory conditions as the DSO. It does not have to meet the single-contingency rule (n-1), which renders the operation of a feed-in grid comparatively cheap. This means that in principle, system reliability can expected to be lower. However, it can be expected that underground cables in rural regions are only rarely damaged (pers. communication with R. Pforte, BTU Cottbus, 13.03.2009). The overall effect of these two aspects has not been publicly quantified yet.

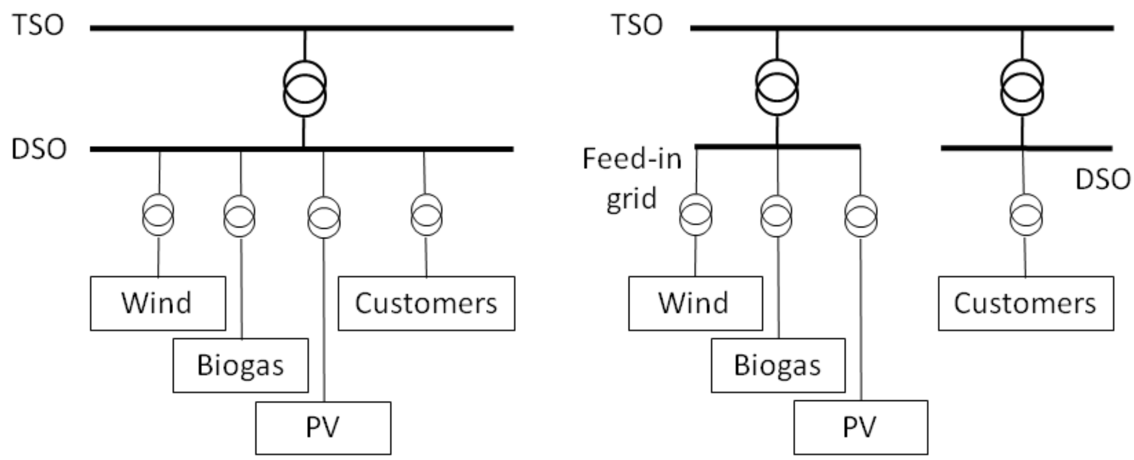

Figure 1: Concept of the feed-in grid. Left: Conventional connection to the DSO network, right: Connection via a feed-in grid; based on Schwarz et al., 2008, p. 35

3.2 DER and network regulation in Germany

The current German support scheme for renewable energy is the Renewable Energy Sources Act from 2009 (Erneuerbare-Energien-Gesetz, EEG 2009). It can be classified as a feed-in tariff (FIT) with a decreasing remuneration based on the year when the DER unit was started (degression) and an opt-out possibility for full months. This means that a fixed technology-specific tariff is paid to all eligible DER units unless these announce in advance that they reject the right to obtain the FIT from a certain month onwards. In this case, they can sell the generated electricity directly. Returning under the safe FIT income is possible with the same notification period as stepping out of it. This mechanism is intended to support the direct marketing of renewable electricity, which also comprises balancing in case of deviations from the announced generation plan. For units under the FIT scheme, this is done by the TSO and the resulting costs are recovered together with the FIT costs from the final customers.

DER units have a priority connection right to the closest network and have to bear the costs arising from the connection to the network. It is the network operator's duty to strengthen the network; resulting costs can in principle be recovered via the use-of-system charges for all consumers. The German FIT of 2004 allows the curtailment of FIT units if the network capacity is fully used. However, such a situation can only occur if the network operator did not or could not fulfil reinforcement and extension measures fast enough, e.g. due to the fact that permission periods for overhead lines can exceed 10 years. The detailed practical handling of the curtailment is beyond the scope of this paper. From 2009 onwards, the legislation has been changed in such a way that the network operator has to remunerate the DER operator with the FIT even if the generation of the unit has been curtailed. If the delay in grid reinforcement is not the network operator's fault, resulting costs can be passed on to the consumers via use-of-system charges. A special conflicting constellation arises with regard to grid expansion: network operators are legally bound to choosing the cheapest option, which are commonly overhead lines at the high- and extra-high voltage level. In Germany, over 10 years can pass between the first planning and final erection of the line, which is mainly due to administrative procedures. Permission for underground cables can be obtained much faster, but their cost competitivity in comparison to overhead lines is currently subject of ongoing discussions. They are concluded to be more expensive in a number of studies (see Brakelmann, 2004, pp. 115-116 for an international overview). This results in the combination that in some cases of rapid regional DER development, additional units can hardly be connected or had to expect severe income curtailment from 2004 to 2008.

In Germany, the Renewable Sources Energy Act is coordinated by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. However, all other relevant legislation is within the scope of duties of the Federal Ministry of Economics and Technology. More precisely, this covers the Energy Act (EnWG, 2005) and related regulations which provide rules for network tariffs (StromNEV, 2005) and the overall TSO's and DSO's revenue caps (ARegV, 2007). A regulation giving guidance how DER units should be considered when planning network reinforcements has not been issued yet, although it is explicitly mentioned in the Energy Act (§14). It can be concluded that the field of DER grid integration is regulated by different political and administrative entities, which can lead to differing point of views about how to design regulation.

3.3 TSO perspective

In principle, the TSO is subject to the same grid reinforcement and extension requests as the DSO: the network needs to be adapted to changing load flows in a cost-effective way. This means that the extra-high voltage grid should be expanded with overhead lines, accepting the associated delay in comparison to underground cables. In Germany, a legislative initiative attempts overcome this situation by supporting the erection of underground cables at the extra-high voltage level (EnLAG, 2008). The need for network reinforcement can be substituted in single cases, e.g. through a maximum feed-in that is lower than the sum of all additional generation capacities. This is only possible through coordination of DER units with a guaranteed overall output. In a bundling of DER into a virtual power plant (VPP), membership of DER units in different VPP portfolios can change over time. A VPP does therefore not have an effect on the necessary grid development. However, a physical bundling of DER units with a reduced overall capacity can ensure that network development becomes less distinct.

Another important aspect is that the TSO is responsible for the system reliability and related energy flows. In contrast to most conventional energy sources, which can be scheduled with a high reliability, renewable sources are naturally variable and scheduling is only possible under certain forecast errors. For this reason, it is reasonable to assume that a TSO has an interest in a) keeping the capacity sum of all DER units small and b) supporting system-immanent levelling and storage of variable units.

3.4 DSO perspective

The DSO faces analogous regulatory requirements as the TSO, but is not responsible for the stability of the whole system. An aspect which touches the DSO more than the TSO is self-generation or generation very close to the load centre and the resulting reduced network usage. The DSO does not profit from DER generation if only consumers pay use-of-system charges and their self-generation increases. DER can therefore be seen as a threat to the DSO's core business, energy transmission from the superior network to the customer. Joode et al. (2007) conclude that DSOs do generally not benefit from the presence of DER in their networks; if a DSO can benefit, it is in most cases under circumstances with a low DER penetration rate. Having this background, the DSO will grant grid access to DER units in a way which it is legally forced to, but not pursue an active approach. If the regulatory constellation is such that DER is an economic burden to the DSO, it will prefer a bypass of its own network through the erection of a parallel feed-in grid. This implies that a parallel network at the same voltage level will be constructed, but with a considerably different function and topology: the DSO network is characterised by a large number of customer connections at different voltage levels, whereas the parallel grid is designed for feed-in at single points and voltage levels only. A feed-in of DER generation into the feed-in grid means that, in an extreme case, this will be transformed up to the TSO's extra-high voltage grid and then transformed down to the DSO's low-voltage grid again although generator and consumer are next to each other. Both the TSO and the DSO do thus not experience a decrease in demand, which means that their use-of-service charge revenue will not be affected by DER. However, it cannot be excluded that customers choose direct connections to the feed-in grid, e.g. cold storage houses which can be used as thermal storages. In this way, the natural monopoly of the DSO can be undermined in the long run.

3.5 DER operator perspective

3.5.1 Grid owner

The grid owner operates the feed-in grid and the connected generation and storage facilities. He bears the feed-in grid planning and building expenses as well as the following operational expenses. The economic reasoning is that these will be outweighed by the following advantages:

- Reduced curtailment risk: The curtailment risk is the net difference of opportunity curtailment risk (when connected to the DSO) and the presumably higher network unavailability due to technical failures. This is due to the fact that the private feed-in grid does not have to meet reliability criteria (e.g. the n-1 which applies for public networks). If the generation of single DER units can be curtailed by the DSO when its grid is congested, a feed-in grid can serve as a bypass. For the DER operator, this implies a revenue stream in these hours as well as reduced maintenance costs caused through additional stops and upstarts of the machinery.

- Lower grid connection cost when planning new installations: The connection of additional DER units to the DSO grid comprises a certain risk that it could be delayed and become more expensive due to organisational matters (transaction costs). These can be avoided if the additional unit is to be connected to own grid infrastructure.
- New business fields: The DER operator has the possibility of obtaining additional income through different channels. It physically combines its single DER entities, possibly with storage units, and can therefore generate additional revenue. Under a feed-in tariff, this could be remunerated with a bonus for a less fluctuating power supply or for an adaptation to a certain load profile. In the liberalised markets, it offers the possibility of participating in ancillary service markets, e.g. for regulating power.
- Use-of-system charges from third parties: Other DER operators could exhibit a willingness to pay for being connected to the feed-in grid instead of the DSO network if the latter comprises a curtailment risk. The inclusion of demand-side units in the feed-in grid is also possible: Especially flexible customers (e.g. cold storage houses) could wish to be connected where their flexibility is an economic advantage to the grid owner. This implies that they will cover their electricity demand via the feed-in grid, which means that they will pay use-of-system charges to the grid owner. It is beyond the scope of this article to discuss whether these charges would be agreed bilaterally between the grid owner and the connected third party or whether they need to be regulated transmission tariffs.

All of the above mentioned points are subject to regulatory risk, i.e. changes in the regulatory framework. A practical example is that for Germany, the curtailment risk has been abolished with the new Renewable Energy Sources Act (EEG) 2009. The investor's benefit of erecting a feed-in grid depends therefore highly on the long-term development of the relevant legislation and regulation.

3.5.2 Competitors

The following elaborations are based on the assumption that the competitors are connected to the DSO's network.

From an operational point of view, other DER operators in the region with the feed in grid are not at a disadvantage in comparison to a situation without a feed in grid. They can connect to the DSO grid under the same conditions as without the feed-in grid. In a case of a constrained network situation with curtailment, they might even profit indirectly from the parallel feed-in grid because curtailment times are reduced. However, when planning a new facility, they have a competitive disadvantage in comparison to the feed-in grid owner. This covers a higher risk premium for grid connection costs to the DSO as well as the comparative disadvantage that the feed-in grid owner is more represented among regional stakeholders. The single generation units can still be grouped to a virtual power plant, which allows coordinating their operation and participating in spot and regulating markets.

	Feed-in tariff	Self-marketing
DSO network	Reinforcement: Network customers Levelling/regulating: Feed-in tariff paying parties	Reinforcement: Network customers Levelling/regulating: Private investor
Feed-in grid	Reinforcement: Private investor/ feed-in tariff paying parties Levelling/regulating: Private investor/ feed-in tariff paying parties	Reinforcement: Private investor Levelling/regulating: Private investor

Table 1: Cost bearers of alternative integration scenarios

3.6 Ownership issues

The EU directive 2003/54/EC distinguishes a 'direct line' and electricity 'distribution'. The direct line is defined as "either an electricity line linking an isolated production site with an isolated customer or an electricity line linking an electricity producer and an electricity supply undertaking to supply directly their own premises, subsidiaries and eligible customers". Contrarily, the definition for distribution is "transport of electricity on high-voltage, medium voltage and low voltage distribution systems with a view to its delivery to customers, but not including supply". It shows a clear focus on transmitting energy to final customers, which is not the goal of a feed-in grid. This exhibits more similarities with a direct line and is therefore not bound by the unbundling rules stated in the Directive. Commonly, the planning of DSO network reinforcements and additional DER capacity takes place separately. This is due to various factors, such as different planning horizons (DSO: 40-50 years, DER operator: 20-25 years), uncoordinated intermittency of DER units and a lack of organisational integration. It is extremely costly to develop network infrastructure to a point where it can absorb DER generation in all hours of the year, which does not lead to the socioeconomic optimum. Under a curtailment regime, the common ownership of the grid infrastructure and DER units can solve this problem. With the opportunity remuneration solution for curtailed generation implemented in the new German EEG 2009, a similar effect can be reached. However, additional instruments would have to be implemented to coordinate other factors of grid-DER interaction, e.g. for the local provision of reactive power. These instruments are obsolete in the case where DER units are connected to a grid owned by their operator.

4 Results

4.1 Cost and benefit analysis

For the cost allocation analysis, two cases are regarded separately: a standard case where DER units are connected to the DSO's network (with necessary reinforcements) and a case where these are connected via a feed-in grid. This is combined with two possible remuneration scenarios: the generated electricity can either be sold under a feed-in tariff regime or by self-marketing on the respective spot and regulating markets.

Table 1 gives an overview of the four possible cases of cost allocation. It attempts to derive the final cost bearers, e.g. the network customers because the DSO can in principle pass on additional expenses.

In the first case, DER units are connected to the DSO network and are remunerated with a feed-in tariff. The reinforcement costs will indirectly be borne by all network customers under shallow connection charges, as they are applied in Germany. This mechanism leads to regional differences in use-of-system charges for DSO customers: those living in regions with a large DER penetration pay a disproportionately high amount of DER integration (dena, 2008). A curtailment option allows the DSO to reduce network reinforcement or optimise its level. This depends on the detailed design of the curtailment regime; for the DER operator, it is decisive whether the DSO has to remunerate curtailed generation. The levelling of fluctuating generation and the regulation for short-term deviations from plan are indirectly paid by the feed-in tariff paying parties: the TSO is responsible for these actions and can forward net costs to the charged parties. Contrarily, this would directly be done by the private feed-in grid investor in a liberalised market. This case can be seen as the future standard case once DER do not rely on financial support anymore.

In the second case, DER units are connected via the DSO network, but the private investor chooses self-marketing. The network reinforcement costs and curtailment discussion is analogous to the first case, but levelling/regulating power expenses are borne by the private investor. It is reasonable to assume that they will group several units to a virtual power plant to keep balancing costs low.

In the third case, DER units are connected to the TSO network via a feed-in grid and the private investor covers all expenses. Under a feed-in tariff scheme, these will indirectly be paid for by the tariff-paying parties. Such a constellation can most likely be expected under curtailment due to congestion in the DSO system and under a deep connection charging regime, whereas the charges are shallow in Germany. The difference between site, generation and maintenance costs and revenue under the feed-in tariff is the private investor's risk and will generally lead to a legitimate profit. The existence of a feed-in grid under such a scheme can be interpreted as evidence that substantial benefits arise from establishing this parallel network infrastructure, e.g. through a faster connection and earlier DER unit upstart. Nevertheless, as feed-in tariffs are adjusted to a level where grid reinforcement does not have to be paid for (shallow connection charges), the voluntary erection of a feed-in grid by a private investor (which is equivalent to paying deep connection charges voluntarily) can imply two things: first, the feed-in tariff subsidisation level is too high - this suboptimal efficiency is inherent to the policy instrument. Second, there must be considerable disadvantages in relying on a connection to the DSO grid in comparison to establishing an own one. However, it should be noted that this reasoning holds only for a situation where the private investor will stay under the feed-in tariff permanently. If the private investor intends to sell the generation on liberalised markets instead in the future, the feed-in grid can allow for additional income (see section 3.5.1). A central benefit can arise if the feed-in grid's transmission capacity to the TSO is substantially lower than the sum of all single DER capacities: in this case, the TSO does not have to reinforce its network as much as under the alternative case. In other words, it benefits from the effect that the feed-in grid has similar characteristics as a virtual power plant with a lower guaranteed total capacity.

The fourth case represents this combination of a feed-in grid and self-marketing of electricity generation. The only difference is that the private investor does not obtain his revenues under a feed-in tariff scheme, which means that he is affected by a higher risk. The new erection of feed-in grids under this case means that the DER portfolio is not only competitive in liberalised markets, but that it constitutes a competitive advantage that justifies the additional capital expenditure. The argumentation for curtailment and connection charges is analogous to the third case, just as it is for possible TSO benefits.

4.2 Long-term implications

In the long run, the gradual extension of a feed-in grid that is separate from the DSO network can lead to the effect that single customers choose to be connected to either both networks or the feed-in grid only. This is especially valid for consumers with flexible demand because they exhibit storage characteristics and can therefore be beneficial for the feed-in grid. With different interconnections to DSO and TSO networks or an extension towards a more meshed structure, the feed-in grid could, in the long run, challenge the regional natural monopoly: If its operation is profitable without use-of-system charges, it would be even more with them. It is currently expected that the flexibilisation of the demand side with smart metering technology can facilitate the integration of DER substantially. At the DSO level, this effect is reduced if DER generation and final customers are only connected indirectly at TSO level.

5 Discussion and conclusions

This paper has analysed the option of feed-in grids that collect the generation of DER units. The owner of the feed-in grid and the connected units is assumed to be identical. This offers advantages for the operation of the grid because the quality of service level can be lower than in the DSO network and because generation can be coordinated better with the network, e.g. for the local provision of reactive power. However, the occurrence of a feed-in grid that is parallel to existing network infrastructure could rather be expected in a country with a deep connection charging regime for generators. In this case, the DER operator has to bear all costs of network connection and reinforcement. It could thus be cheaper to establish an own network between several units that does not have to meet the single-contingency criterion. It is surprising to notice that such a feed-in grid seems to offer economic benefits in a country with shallow connection charges as well. In this case, the feed-in grid operator voluntarily invests a far larger sum than he is obliged to. A possible explanation is that DER facilities can be connected faster to the own network and thus, an additional degression step of the feed-in tariff can be avoided. Other economic benefits seem rather limited under a feed-in tariff without a special remuneration for aggregating several DER units to a power plant with a more reliable generation and lower peak generation. Under a situation where the DSO could curtail DER generation because of a congested grid situation due to a too slow reinforcement, the incentive to bypass the congested grid with own infrastructure increases. Furthermore, planning security for additional DER units in the region is increased for the feed-in grid owner. The existence of parallel grid infrastructure is nevertheless astonishing and there should be economies of scale of integrating both networks. If a private investor can erect new network infrastructure faster than the DSO because he is not subject to the same economic constraints, these should be relieved from the DSO.

A drawback of the presented paper lays in its qualitative nature: an overall socio-economic evaluation is not possible without a quantitative evaluation. For network investment, this is typically only possible on a case-by-case basis. The author suggests that exemplary case studies could be the topic of further research. He considers it highly important to take a holistic investment view for such a study: the mere comparison of investment options at lower voltage levels (i.e. DSO/feed-in grid) would neglect possible benefits that arise from the coordination of DER units with storage options. This leads to a reduced peak generation, which can imply a lower reinforcement need at the TSO level. The main advantage of a feed-in grid with a lower peak generation lies in the physical constraint in comparison to virtual power plants, where the total output is not capped and not coordinated with network reinforcement.

A policy recommendation that can be derived from this dilemma is that virtual power plants that are interconnected by a DSO grid can constitute an economic benefit for the TSO. DSOs and TSOs should remunerate the virtual power plant operator bilaterally for guaranteeing a maximum feed-in from the virtual power plant over a longer time horizon, if this leads to reduced capital expenditure. It is important that such expenditures are treated on a level playing field with opportunity investment under national economic regulation. The practical implementation of this approach can be seen as a challenge in combination with the versatile impacts of more DER units on DSO economics. Furthermore, the separation of DER generation in a feed-in grid and electricity demand in the DSO network complicate the integration of both factors; power flows would always pass via the TSO network and therefore also lead to use-of-system charges at the TSO level.

In the long run, a network infrastructure that is parallel to the existing DSO network could challenge the natural monopoly of electricity distribution. It is argued that first, consumers with a high price elasticity could connect to the feed-in grid to realise benefits from their storage characteristics. The market and contractual relations should be designed in a way that DER operators can benefit from the positive effect of the feed-in grid without actually having to make such an investment. If qualitative analyses should prove that parallel network infrastructure is beneficial under certain circumstances, the DSO should be incentivised to engage in the investment. This does allow the conclusion that private investors should be restrained from establishing feed-in grids because they can facilitate the fast integration of DER in the energy system.

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