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The fundamental evaluation of the methodology of constrained connection for Distributed Generation for procuring flexibility in European countries –lessons for Japan-

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SUMMARY

Recent increase of Distribution Energy Resource (DER)s in distribution level drives the concept of "active DSO". The one of buzzword is flexibility, which active DSO procure and utilize. With respect to generation connection, some DSO is considering the possibility of "constrained connection" by which DG is connection conditional on the curtailment. Some European countries consider this constrained connection can defer additional investment and suggest different approaches for constrained connection. Japanese government and electric power companies have interested in the pros and cons of constrained connection. The experiences of the early adopters would give valuable information and help other countries to learn about the potential benefit of constrained connection. When the constrained connection is introduced in each country, it is important to consider the consistency between the rule and principle of constrained connection and the respective rule of network usage tariff.

KEYWORDS

Flexibility, generation connection, curtailment of generation output, user-pays principle, network usage tariff, active Distribution System Operator

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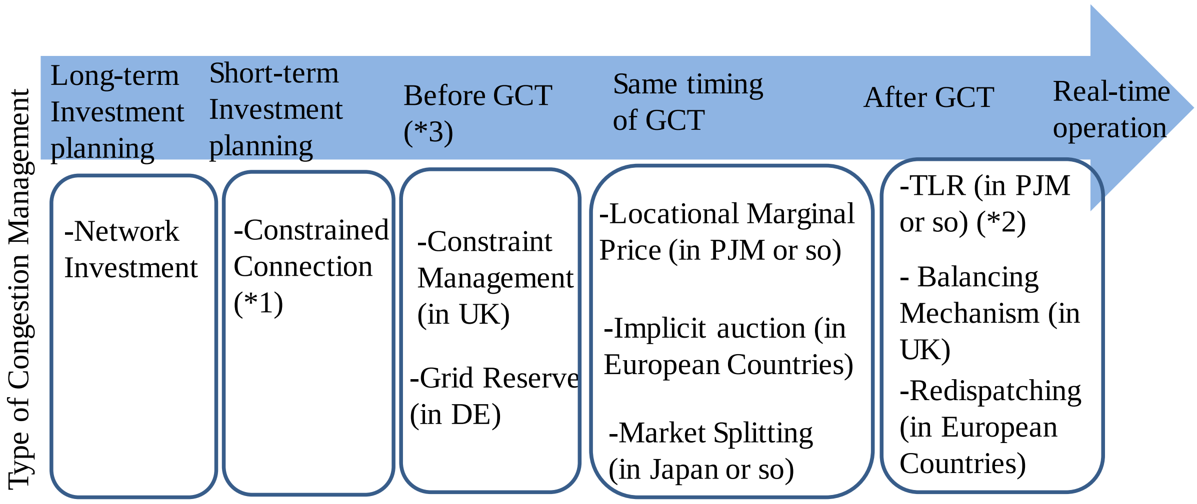
1. INTRODUCTION

Recently a large amount of distributed Energy Resources (DER) including intermittent generation (like photovoltaic and wind farms) and Distributed Generation (DG) like diesel-engines have been installed into distribution network because of Feed-in-Tariff (FIT) schemes or Renewable Obligation (RO) in many countries, including European countries and Japan. A rapid increase in installed DER with subsidies has posed challenges for Distribution System Operators (DSOs) in their management of the network. Namely, it has been increasingly difficult for a typical DSO to manage network congestion caused by variability of output from DG without sufficient capacity of the network. Since most renewable subsidy schemes require DSOs to connect renewables to the network, DSOs eventually have to increase investment to accept all the requests of DER connection. The increase of investment would lead to a long queue for DER connection and a higher network tariff, which has to be borne by network users including DER. This situation motivates the concept of “active” DSOs regarding network management, including investment planning, connection, and operation. An example of active network operation is the control of DER output in real-time in order to maintain the power flow and voltage within the network constrains by utilizing technology of sensor and forecast. By controlling the output of DER effectively, an active DSO can accept the connection requests and operate the distribution network efficiently while deferring additional investment. In order to realize such network benefits, an active DSO can implement a so-called “constrained connection” of DER as an option of DER connection. The constrained connection is defined as a DER connection to the network with the possibility of curtailment of the DER output; the owners of DER accept the curtailment if the network constraint happens. It is also called “flexible connection” or “smart connection” at DSO level in Europe. This constrained connection agreement could avoid additional investment cost for the DSO and reduce connection fee and shorten the connection queue for the owner of DG as well as network tariff for all network customers. European DSOs and regulators are developing this idea of “constrained connection,” as it is believed to be a “win-win” solution for both DSOs and DG owners. Although several approaches for constrained connection are proposed or implemented in Europe, feasibility or effectiveness of different approaches has not been much discussed in the literature, and it is not clear whether those approaches can be implemented in other countries. The purpose of this research is twofold. First, to investigate the pros and cons of “constrained connection” of the case studies in Germany, France, and UK. Second, to clarify the applicability of the different approaches to other countries, which have not yet installed constrained connection. Policy makers, whose country does not start constrained connection, can consider whether they are able to apply for constrained connection in their own countries with consistency of connection fee and network usage tariff. The Japanese government and electric power companies have started to investigate the pros and cons of such a connection methodology recently for the transmission network. Learning from the ideas and experiences of some European countries would be particularly useful, as they need to deal with the problem of integrating DG into electricity market and power system while minimizing the cost of network expansion.

This paper is organized as follow: the next section explains the general congestion management at each timing and novel methodology. Section 3 is described some practical examples of constrained connection at distribution level in UK, France and Germany. Section 4 evaluates different approaches of constrained connection with respect to cost allocation. Section 5 concludes my discussion and points to a future direction.

2. PROCUREMENBT OF FLEXIBILITY FOR CONGESTION MANAGEMENT

Recently a large part of DER, which are installed in distribution level cause some issues about the upgrade of network. These installed DER case unanticipated issues on electricity market,



*1 Constrained Connection: a generation connection to the network with the possibility of curtailment of the output is called "constrained connection" in this paper.
*2 TLR: Transmission Loading Relief
*3 GCT: Gate Closure Time
Fig. 1 Type of methodology of congestion management (Hoshino H. et al. 2019)

power system operation and investment planning (Brandstatt C. 2011, BnetzA 2019 and OCCTO 2019). One of large issues is congestion management. Congestion management is implemented in each timing about investment planning and power system operation (Fig.1). Network operators can accept additional generation or demand connection when network operator upgrade transformer about long-term investment planning. Market splitting or implicit auction can allocate the network capacity with market mechanism about same timing of GCT. Zonal transmission usage tariff can be considered one of congestion management from the viewpoint of long-term.

The ability of congestion management becomes more important. Recently flexibility becomes a buzzword for solution of congestion management. Flexibility is defined as the modification of generation injection and/or consumption patterns, on an individual or aggregated level, often in reaction to an external signal, in order to provide a service within the energy system or maintain stable grid operation (EDSO and Eurelectric 2018). According to Ecorys and ECN (2014), "flexibility is here defined as the ability to adapt and anticipate to uncertain and changing power system conditions, in a swift, secure and cost efficient manner." The flexibility has effects on (1) frequency ancillary services, (2) non-frequency ancillary services such as congestion management, and (3) trade in energy market (CEDEC et al. 2019). The flexibility such as above-mentioned (1) and (2) has been procured for load-frequency control and congestion management by TSO. Recently the flexibility from decentralized distribution level is emerging. Brunekreeft G. (2017) summarize the reason of emerging the flexibility from distribution level, that is (1) the roll-out of smart meters allows utilizing the potential of decentralized flexibility, (2) third parties consider one of the business models, and (3) the intermittent generation makes it more difficult for network operators to control frequency and to alleviate network congestions. Now each country is considering appropriate rules, regulations and market designs in order to procure and manage this flexibility efficiently.

Some European countries consider the methodology, that is network operator can procure the flexibility since the timing of generation connection, is important. The schematic image of constrained connection is shown in Fig.2. When new entry DG requests to connects into power system and Available Transfer Capacity is not enough for new entry fully, network operators can suggest constrained connection as an option. If DG owner choose the constrained connection, DG owner can access the network early because of not necessity of

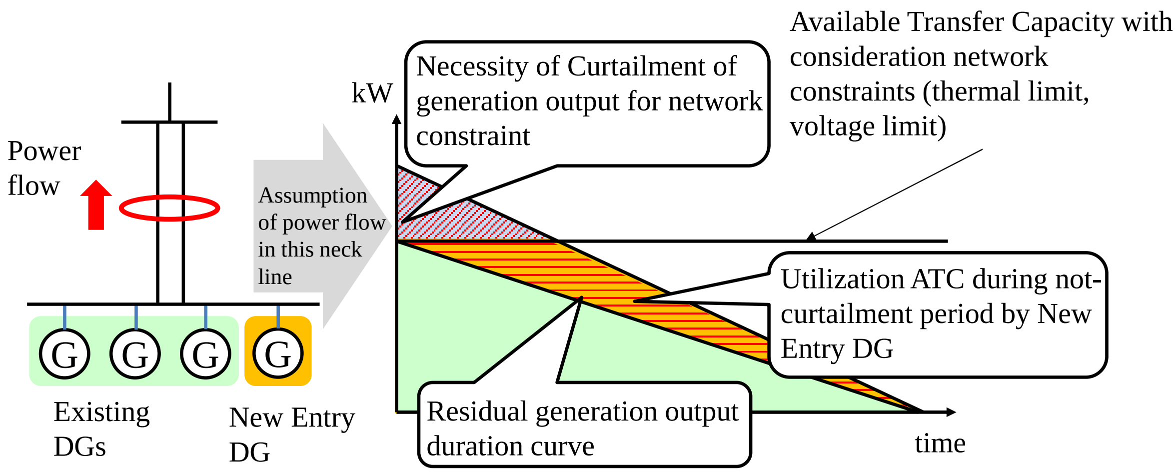


Fig. 2 A schematic image of constrained connection (Furusawa K. 2019b)

additional investment by network operators. DG owner can avoid large amount of connection fee when DG owner is required to pay a part of connection cost. All network user does not need to pay the network usage tariff without additional investment. However, someone has to pay the opportunity cost for the curtailment of generation output (i.e. the opportunity cost is recovered from network usage tariff via network operator, imbalance price, balancing market, or the decrease of income of DG owner). About these benefit and cost allocation, the methodology in each country is different.

3. CASE STUDY OF CONSTRAINED CONNECTION OF DG (Furusawa K. et al. 2019a)

In UK, France, and Germany, DSOs start to consider the procurement of flexibility since the timing of generation connection.at distribution level.

3.1 Feed-in-Tariff and three percent curtailment rule in Germany

The Feed-in-Tariff (FIT), which was introduced since 2000, has guaranteed the fixed income of DG for 20 years. It is worth noting here that the owners of generation in Germany do not have to pay network usage tariff and pay connection cost based on a shallow approach[1]. In the future, Germany will continue to install DG including RES so that RES energy is expected to account for 50% of total demand by 2030, 65% by 2040, and 80% by 2050. However, in order to connect such amounts of RES, the cost of the required network investment at the DSO levels is expected to increase by 27.5 billion to 47.5 billion EUR by 2030 (DENA-VNS, 2012). In general, the curtailment RES output can bring cost reductions of network investment. Thus, in order to minimize the grid development cost while maintaining the income protection of DG, German government introduced the “3% curtailment rule”, proposed by BMWi (2014). The 3% curtailment rule implies that DSOs can make the investment planning conditional on a 3% curtailment of the DG output per year. DSO can implement feed-in management before and after this 3% curtailment rule by static peak shaving system, on and off signal system, and stepwise control system. Compensation cost of feed-in management will be paid to the owner of DG if their output is curtailed. Therefore, the income of DG will not be reduced by feed-in management. As a result, the compensation cost

[1] In this report, shallow approach means the owners pay the construction cost of the new line to connect to the existing network, while the network operators have to pay for the upgrade cost of the existing network if it is necessary. A deep approach means that the owners pay both costs. Semi-shallow approach means the hybrid of shallow and deep approach.

for the curtailment of RES and network investment cost are recovered from final consumer in Germany.

3.2 Smart connection in France

In France, connection cost had been high, and connection request was handled individually, so that it was particularly difficult for a single DG owner to bear the cost. In order to reduce the connection cost, a new scheme called "S3REnR (regional renewable energy network connection schemes)" was implemented. Under the S3REnR, DSOs can suggest individual payment or coordinate the multiple requests to share the connection cost. Despite this scheme, the long queue and the high investment cost of the generation connection remained as a big issue among French stakeholders. As a result of these concerns, one French DSO and regulator discussed other countermeasures and selected the constrained connection, called "smart connection", as a possible solution. By smart connection, the French DSO expects a decrease in the investment cost and in the delays of network connection. DSO offers two types of connections (conventional connection and smart connection) as the DSO receives a connection request from DG. When DG owners select smart connection, they have to accept the possibility of curtailment of the output of DG. By this smart connection, however, the owners pay less connection cost and it shortens the delay by some months as compared to that of conventional connection. At the moment, smart connection is in an experimental stage for a period of two years only in a specified area since 2017. It is expected to realize a net gain of 65 million EUR for the connection of 720 MW of additional production to the existing feeders at a national-level (Enedis, 2017). Under smart connection, the DSO cannot control the output of DG directly. Regarding the actual curtailment of DG connected by "smart connection", the DSO forecasts power flows in D-1. If there is a possibility of congestion in the network, the DSO requests a curtailment of the output to the producers by asking to set the limit of the output from DG. The DSO recalculates the power flows intraday every 30-minutes and it can request again to the producers after the recalculation. There are two types of curtailment methodologies (warranted capacity and warranted energy) for French DSO[2]. There is no compensation for the curtailment energy in France.

3.3 Flexible connection and Active Network Management in UK

In the UK, the policy to promote DG was RO (Renewable Obligation) since 2002 and FIT was introduced since 2010. The owners of DG have to pay the connection cost that exceeds a certain amount (it is called semi-shallow) and network usage tariff. DSOs in the UK prefer smarter power system operation enabled by monitoring network constraints and controlling the output of DG. Such smarter power system operation is called "Active Network Management", the idea of which is to provide a cheaper and faster distribution connection to the electricity distribution network. Initially, DSOs in the UK had tested "timed/profiled connection". Timed/profiled connection means that prior to the connection, the DSO informs about the possibility of scheduled curtailment during the designated period with reference to the load profile. During the power system operation, the DSO could curtail the output of DG by a fixed volume during the informed period. "Flexible connection" as an optional procedure, introduced after the experiment of timed/profiled connection, allows curtailment without specifying the time period of doing so. It enables DSOs to implement more flexible operation by flexible connection. The smart devices need to be rolled out in order to monitor the network constraints and curtail the output of DG. There are two types of flexible connections in practice. One is LIFO (Last-In-First-Out), the other is prorate. The owner of DG cannot

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[2] The minimum injected capacity is guaranteed by warranted capacity. The minimum injected energy is guaranteed by warranted energy.

choose between LIFO and pro-rata. It is the DSO to select the curtailment methodology in each control area. In some earlier studies (E.g. Anaya and Pollitt 2012), pros and cons of LIFO and pro-rata have been discussed. LIFO is a consistent approach with the conventional “first-come, first serve” principle. The last generator would never be inclined to connect due to the high level of curtailment possibility. However, if the last connected generator is newer one with high efficiency and the first connected one is an old generator with low efficiency, LIFO is not an optimal curtailment methodology. Pro-rata, on the other hand, is considered a neutral approach and the DSO is able to fully utilize its network capacity. As more DG is connected, however, the capacity available for each of the DGs already connected will be smaller. The market-based capacity allocation is considered efficient (Anaya and Pollitt, 2012). However, it requires a new market system to be installed. The cost of this new market-based capacity allocation would be high, and, moreover, the system will be useless after network investment or reinforcement. It is important to analyse the cost-effectiveness of this approach. The opportunity cost for curtailment and a part of network investment cost is paid by DG owner selves in UK.

3.4 Steps of Japanese connect and manage (OCCTO 2018)

Organization for Cross-regional Coordination of Transmission Operators (OCCTO) starts to consider the Japanese connect and manage (C&M) in transmission level. (1) Generator shedding in N-1 situation is a C&M connection method that a portion of transmission capacity reserved for emergencies is utilized also in N situation provided that generators are able to shed their output instantaneously in N-1 contingency by a relay scheme. (2) Non-firm access is a C&M connection method that the generation output can be curtailed by following TSOs’ orders even in N situation. The methodology of curtailment will be implemented in 2 stages, namely tentative and full implementation stages. In the tentative implementation stage of (1), implemented in Oct. 2018, the method for generator shedding in N-1 situation is assumed to be Last-in First-Out (LIFO), and finally pro-rated among all concerned entities if the situation sustains. And for tentative implementation stage of (2), priority is given to firm generation by first of all securing generation in day-ahead spot market or bilateral contract. Non-firm generation can then utilize the residual capacity through the intraday market etc. In the full implementation stage of both (1) and (2), a generator may be ordered to curtail its output on behalf of those who should curtail their output. In such case, it is considered to compensate them with opportunity cost, and the details are under discussion. OCCTO and Electricity and Gas Market Surveillance Commission (ESC) will consider the policy or rule, which consistent between capacity allocation for network usage and network usage tariff with generation component.

4. A FUNDAMENTAL ANALYSIS CONSTRAINED CONNECTIONS FOR JAPAN

From the above-mentioned examples, we evaluate different approaches of constrained connection with respect to cost allocation. The comparison of pros and cons of constrained connections in UK, France and Germany (Table1). The curtailment of generation output is controlled discretely in Germany. In order to keep network constraints, over-curtailment is necessary. Even if over-curtailment energy happens by discrete curtailment methodology, the DG owner can receive the compensation, which is recovered from final customer via DSO. The comparison between LIFO and pro-rata is not necessary in Germany. The market-based capacity allocation rule such as a discussion in UK implies the introduction of network usage fee from generation-side. For the countries without generation component of network usage tariff it will be difficult to accept this rule. If the compensation cost for opportunity cost is recovered from network usage tariff and DG owner with non-constrained connection in UK pays network usage tariff, DG with non-constrained connection give a subsidy to DG with constrained connection. From the viewpoint of user-pay principle, it is important to consider the consistency of the abovementioned compensation. The deferring the additional investment

Table 1 Comparison of pros and cons of constrained connection in three countries

	UK	FR	DE
DSO	DSO can control the curtailment of generation output remotely and continuously	Automatic algorithm of the curtailment of generation output may be going to be introduced later	There is a possibility of over-generation output curtailment because of on-off control
DG owner	There is no compensation for curtailment of generation output	There is no compensation for curtailment of generation output	There is a compensation for curtailment of generation output by FIT rule

and decreasing the maintenance cost by introduction of constrained connection is able to contribute to decrease the network usage tariff. However, it is difficult to reflect the decrease of locational network usage tariff. One of reason is that there is no locational network usage tariff in Europe and Japan now. The other reason is that it is difficult for DSO to reflect the locational cost-effectiveness on the decrease of maintenance cost accurately.

5. CONCLUSIONS

In this paper, it is discussed that the challenge for DSO to design and implement effective "constrained connection" in some European countries with respect to the cost allocation between DSO, DG owner, and all network users. With the constrained connection as defined as a generation connection to the network with the possibility of curtailment of the output, the owners of DG accept the curtailment if the network constraint happens. The constrained connection can defer the additional investment for some months or a few years. For the owner of DG, the constrained connection may bring the benefit of lower connection tariff, and shorter waiting time for the connection. The other network users also benefit from the lower network usage tariff. This constrained connection has the possibility of "win-win" solution for both DSOs and DG owners. However, this constrained connection is a temporary countermeasure in order to defer the investment. Finally, someone has to pay the cost, which are network investment cost and opportunity cost of curtailment of generation output. In Germany, the network investment cost and opportunity cost of curtailment of generation output are allocated into final customers. In UK, the cost allocation concept is based on user-pay principle among three countries. In France, the cost allocation concept can become similar attitude. It is important to consider the consistency between benefit of utilizing network and payment of network usage tariff.

The energy policy background in promoting DG and the technology available for controlling DG in the country are important for the initial choice of approach for the constrained connection. In order to realize and improve the cost effectiveness of constrained connection in the future, it is necessary to have detailed assessment of relationship between curtailment cost and network investment cost, methods of allocation of curtailment volume and impacts of network tariff structure. This would be a difficult task, but experiences of the early adopters would give valuable information and help other countries to learn about the potential benefit of constrained connection.

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