Study Committee C6

Distribution Systems and Dispersed Generation

Paper ID C6_10595_2022

Examination of NF-type connection power supply for interconnection to the power distribution system

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Motivation

- Under the situation of large amount of PV installation, it is important to use a flexible use of available capacity in networks.
- “Non-firm (NF) connection”, which newly connects generators with the possibility of curtailment of generation output at the time of network congestion, is being carried out on national project (NEDO).
- Although NF is expected to be applied to the transmission system independently, a comparative evaluation of the cost when applied to the 6.6kV distribution system was carried out.

Concept of Japanese NF connection

- **Conventional grid connection**: generators are connected to grids on a first come first served basis within available network capacity.
- NF connection: “Connect and Manage” concept, which enables new generators to connect to grids on the premise of power curtailment when constraints of transmission capacity occur.

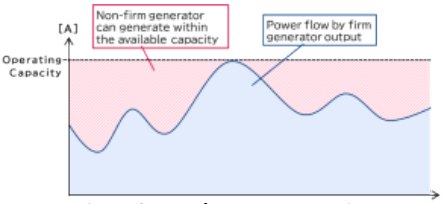

Figure 1 Concept of Japanese NF connection

Introduction potential of NF connections to Distribution NW

- Actual data for each distribution line in the TEPCO area in FY2018 are used.
- At TEPCO, the utilization rate of about 90% of all distribution lines are 30% or less, which means that there are relatively large amount of free capacities.

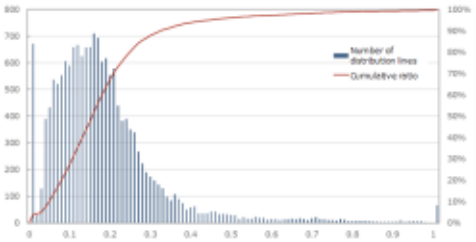

Figure 2 Utilization rate of distribution systems in the TEPCO area

Table I. Estimated results of the introduction potential

	TEPCO area	Nationwide
Number of NF distribution (Introduction potential)	29	50
NF interconnection amount [MW]	83.7 (PV 83.7)	226.1 (PV 221.4)
Output suppression amount [MWh]	16,195	34,681 (PV 34,426)
Output suppression rate [%]	15.2	11.2 (PV 12.1)

Estimation of introduction potential of NF

- New distribution line is to be constructed due to reverse power flow that may cause network congestion in the future; maximum reserve power flow, including the planned interconnection amount by planned generators, exceeds the operating capacity.
- Based on the estimation results of the introduction potential, the cost comparison between NF connections and system reinforcement is carried out by calculating the cost generated by NF connections and system reinforcement.

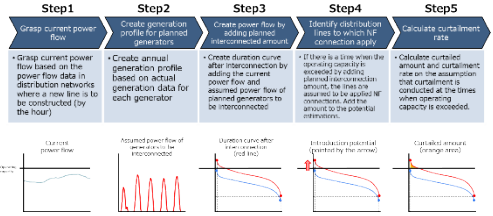

Figure 3. Estimation flow for introduction potential of NF connections

Table I. Estimated results of the introduction potential

	TEPCO area	Nationwide
Number of NF distribution lines (Introduction potential)	29	50
NF interconnection amount [MW]	83.7 (PV 83.7)	226.1 (PV 221.4)
Curtailed amount [MWh]	16,195	34,681 (PV 34,426)
Curtailment rate [%]	15.2	11.2 (PV 12.1)

Cost comparison (NF and system reinforcement)

- Cost for each component is calculated according to Table II, by referring to [6] and [7] as well as experience of TEPCO Power Grid, Inc.

[6])Organization for Cross-regional Coordination of Transmission Operators (OCCTO), “Publication for standard unit price of transmission and substation facilities” (2016) (in Japanese)
[7]“List of useful life of Tangible Cost amortized assets other than machinery and equipment", Appended table 1, “Ministerial Ordinance on the useful life, etc. of depreciable assets” (in Japanese)

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Assumed NF control system

- NF system is based on the assumption to use IT switchgears, which can measure amount of PV generation in real-time and with high accuracy.
- In addition to the system cost, curtailment costs are included in the NF connection costs. Curtailment costs are assumed to be the loss of renewable energy originally planned to be generated, which is calculated by multiplying the curtailed amount shown in Table I by the avoidable cost.
- Other components required for system reinforcement are estimated as shown in Table III

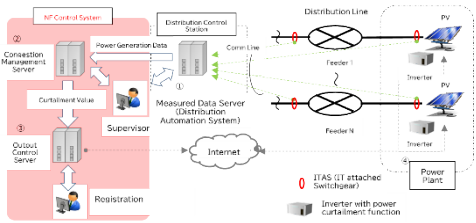

Figure 4 Image of NF control system in distribution systems

Table II Result of cost estimation for components of the NF control system

Component	Cost	Assumption	Lifetime (year)
Output control system	52m Yen JPY/control station	56 stations (TEPCO) 382 stations(nationwide)	6
IT attached switchgear + controller	1m Yen JPY/point	50 lines× 4 points/line	15
Optical cable	1m Yen JPY/km	50 lines× 4.674km /line	10
Maintenance	0.38m Yen JPY/ (month, control station)	382 stations× 12months	–
Labor cost (at control stations)	10,000JPY/ (hour, control station)	292 hours/(year, control station)	–

Table III Results of cost estimation for system reinforcement

Component			Cost [10,000JPY/line]	Assumption	Lifetime (year)
Overhead lines	Power pole		3,819	134	42
	High voltage lines		2,337	4.674km	30
	Automatic switch	Distribution lines with large capacity	963	9	15
		General distribution lines	642	6	
Grounded system	Construction work	Conduit line	375	50m	25
		manhole	2,200	2	25
	Cable installation work		80	–	25
Communication facilities	Optical cable		467	4.674km	10
Total	Distribution lines with large capacity		10,241	–	–
	General distribution lines		9,926	–	–

Cost comparison conditions

- NF connection costs: initial costs for NF system costs, such as output control systems to be introduced to distribution systems for NF operation, are recorded in the year of the introduction, then initial costs for the replacement are recorded for each year of the replacement.
- Curtailment costs: assuming operation period of renewable energy is 20 years, all curtailment costs generated over a 20-year period are recorded in the year of the introduction.

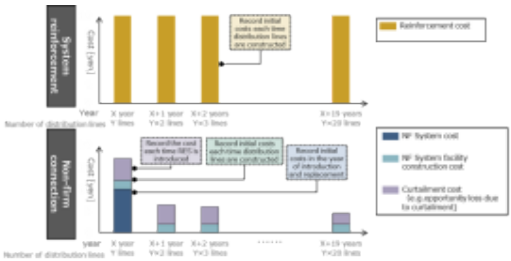

Figure 5 Method of recording costs for system reinforcement and NF connections

Results of cost comparison（TEPCO）

- Average reinforcement cost for 20 years is 2.96 billion JPY (Approx. 24.7 million USD), and NF cost is 4.27 billion JPY (Approx. 35.6 million USD).
- System reinforcement cost is lower than application costs of NF connections when comparing the costs for 20 years.

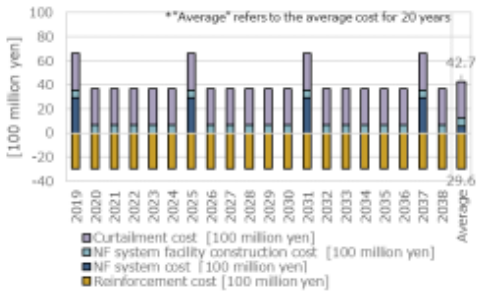

Figure 6 Results of cost estimation: TEPCO area (2019-2038)

Results of cost comparison（Japan）

- Average reinforcement cost for 20 years is 5.08 billion JPY (Approx. 42.3 million USD), and NF cost is 12.27 billion JPY (Approx. 102 million USD).
- System reinforcement cost is lower than application costs of NF connections when comparing the costs for 20 years.

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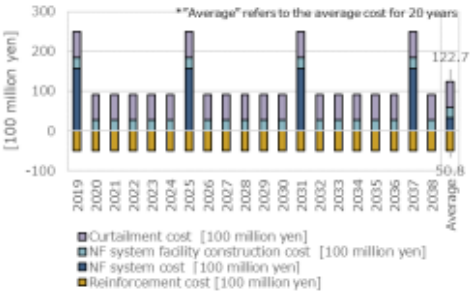

Figure 7 Results of cost estimation: nationwide (2019-2038)

Conclusion

- NF connections are introduced to distribution systems, about 226MW of NF generators can be connected under the condition that NF connections are applied to 50 distribution lines and the curtailed generation amount is approx. 34,000MWh throughout Japan.
- Application of NF connections to distribution systems requires sensor installation and network monitoring in each feeder of distribution systems, since equipment and distribution lines within a distribution system have different allowable current. Furthermore, under the current system in Japan.
- In addition, NF connections to distribution systems are operational challenges; sensor installation and network monitoring , etc.
- Cost estimation in this study was conducted based on present information and assumptions, and results may change due to future changes in the situations.
- Furthermore, with Expected introduction of RES such as BESS and HP to distribution systems, if curtailment amount of RES can be reduced by fully utilizing flexibility provided by such renewable sources, flexible Connect and Manage in distribution systems can be realized in the future.

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