FURTHER VALIDATION AND EXTENSIONS OF THE GLOBAL CAPACITY ANNOUNCEMENT PROCEDURE FOR DISTRIBUTION SYSTEMS

Bertrand CORNELUSSE, University of Liège–Belgium, bertrand.cornelusse@ulg.ac.be
David VANGULICK, ORES–Belgium, david.vangulick@ores.net
Mevludin GLAVIC, University of Liège–Belgium, mevludin.glavic@ulg.ac.be
Damien ERNST, University of Liège–Belgium, dernst@ulg.ac.be

ABSTRACT

This paper extends the Global Capacity ANnouncement procedure proposed in [5] along two directions. First, two new stopping criteria are considered. Second, annual losses are evaluated using representative days to approximate the injection duration curve. The extensions are validated on an updated model of a real-life system. The emphasis is on the situation in the Walloon region of Belgium considered in the GREDOR project [1]. A way for a DSO to publish Global Capacity ANnouncement computation results is shortly discussed.

INTRODUCTION

Achieving high level of distributed generation (DG) penetration in existing distribution systems requires an appropriately designed generation connection procedure. Siting and sizing of DGs is an important technical problem involved in this procedure. Numerous approaches were considered to this purpose [2]. However most of them lack an appropriate consideration of coordination between a DSO and generation connection developer that is of particular importance if the regulatory framework does not allow, or strictly limits, ownership of DGs by a DSO [3,4]. In tackling these issues, we recently proposed the Global Capacity ANnouncement (GCAN) procedure [5,6] aimed at the estimation of the available generation connections capacity in a distribution system. The procedure also identifies the substations that could limit the capacity. The computations are conducted by a DSO and their purpose is to encourage connection developers to start with the projects. The procedure is envisioned to be a starting point of the generation connection procedure, which should be followed by more detailed studies leading to more accurate computations.

Encouraging results presented in [5], using small test and real-life systems, give a momentum for further validation and extensions of the procedure. We further extend the procedure by considering constraints imposed by limitations of load-tap changer (LTC) of connection transformer caused by reverse power flows and the limit on reactive power exchange with the transmission system. These new constraints are easily incorporated in the GCAN procedure as additional stopping criteria. The extensions of the procedure are validated using an updated model of a real-life distribution system operated by ORES, the largest DSO in Wallonia, with a five years planning horizon.

GCAN PROCEDURE

The overall GCAN procedure is illustrated in Figure 1 [5]. It relies on the tools routinely used in the planning and operation of DSOs (load forecasting, network expansion/reinforcement, power flow).

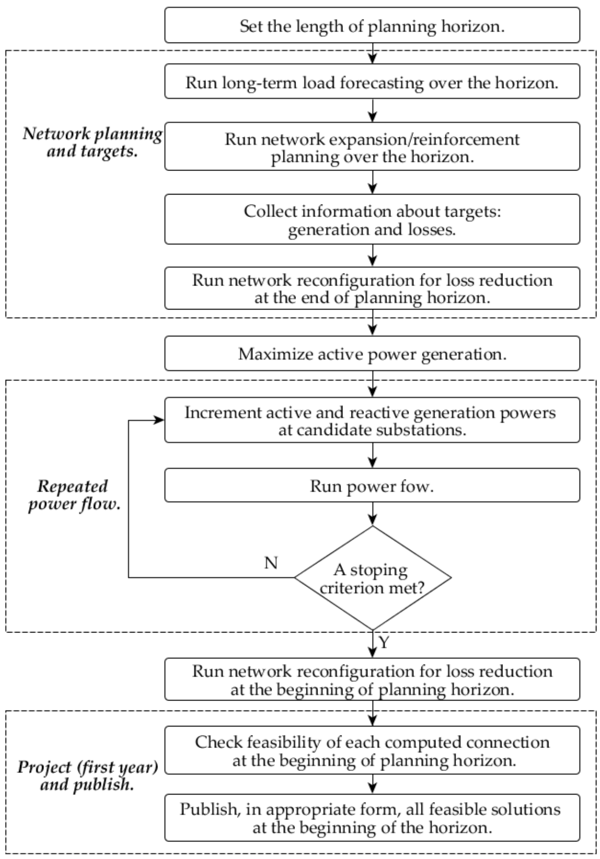

Figure 1: GCAN procedure (adopted from [5])

The computations are conducted for the ending year of the planning horizon and the results are mapped to the first year by simply checking feasibility of each computed generation connection individually.
The procedure is implemented in a rolling horizon manner, over a pre-defined time horizon, allowing the efficient incorporation of the most recent data acquired on the system or any revision in the plans. It is computed at regular time intervals (each year of the planning horizon) or started immediately as soon as any new connection is realized. It is particularly suited for

situations where DSO is not allowed to own generation or the ownership is limited to legacy generations and possible covering of system losses [3,4,5].

The core of the procedure is the efficient implementation of repeated power flow in an automated way [5]. At each power flow run, active generation power is added in every substation depending of the distance to the corresponding upper voltage limit (corresponding reactive power is directly computed depending of chosen technology solution assuming constant power factor). The procedure is stopped if one of the stopping criteria, defined in terms of voltage, thermal, or short circuit level limits, is met.

GCAN EXTENSIONS

The extensions presented in this work include: two practical constraints not considered in the original proposal [5] and an approximation of the injection duration curve through the choice of representative days. The modifications of the GCAN procedure, with respect to the original proposal [5], are shown in Figure 2 (framed in bold lines).

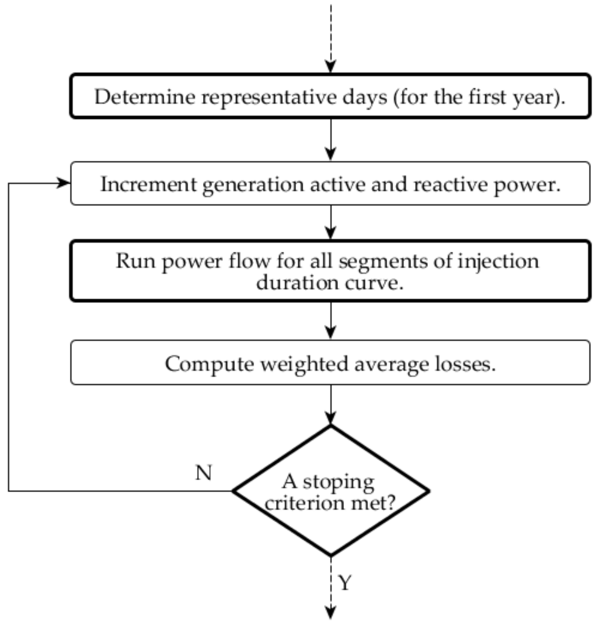

Figure 2: Modifications of the GCAN procedure

The new constraints considered, the limits imposed by the connection transformer due to LTC when reversal power flow occurs, and the limit on reactive power exchange with the transmission system, are added as stopping criteria in the procedure. More accurate estimations of connection powers can be obtained through a better approximation of the injection duration curve for annual losses considerations. The GCAN procedure is further modified by choosing representative days with corresponding "weights" (period of time that each day represents) in line with the method proposed in [7] using the open source implementation [8]. This method employs a mixed integer programming to select a pre-defined number of representative days from given historical data. For each representative day a "weight" is computed representing the duration within the year to which each day corresponds. In the GCAN procedure, this computation is conducted before repeated power flow as indicated in Figure 2. This modification offers better consideration of annual losses at the expense of slightly increased computational burden that depends on the number of pre-defined days.

VALIDATION OF THE PROCEDURE

An updated model of a part of the ORES system is used to validate the procedure and extensions proposed in this work. It is an update of the RL system used in [1] including better representation of the network and system loading and generation patterns (in particular the aggregation of PV generation connected to the low voltage network and new or near future planned wind and CHP generations). A One-line diagram of the system (medium voltage) is shown in Figure 3 while the characteristics of the system are summarized in Table I.

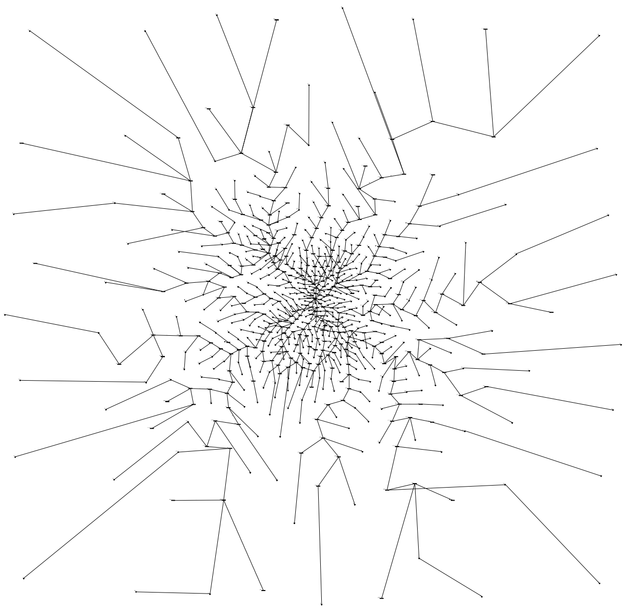

Figure 3: One-line diagram of the network

Table I: System overview

Nb. of subst.	Nb. of lines	$P_{l,total}$ (MW)		$P_{g,total}$ (MW) installed		
		P_{max}	P_{min}	PV	Wind	CHP
328	345	38.80	5.66	6.16	20.5	0.03

As in [5], a five years planning horizon is considered. All substations are considered as candidates for the installation of DGs. Out of 328 substations, nine are considered for the installation of CHP, 11 for wind while the remaining are considered for PV. All bus voltages are constrained to be in the range [0.95,1.05]. The thresholds used are: the minimum limit on amount for generation connection is set to 10 kW (below this value the generations are set to zero), reversal power flow on LTC transformer set to 80% of its nominal power, reactive power flowing into the transmission system is limited to 10 MVAr, the annual losses target is set to 4% of the maximum load in the system. A 3% yearly load increase is considered over the planning horizon. MATPOWER [9] is used for power flow computations in the GCAN procedure, while the whole procedure is implemented through simple scripting making calls to the involved tools (power flow, network reconfiguration, etc.). Figure 4 depicts evolution of the total load and generation during the first year of the planning horizon (at a time resolution of 15 minutes). From these data, eight representative days are selected to approximate the injection duration curve. This curve is shown in Figure 5.

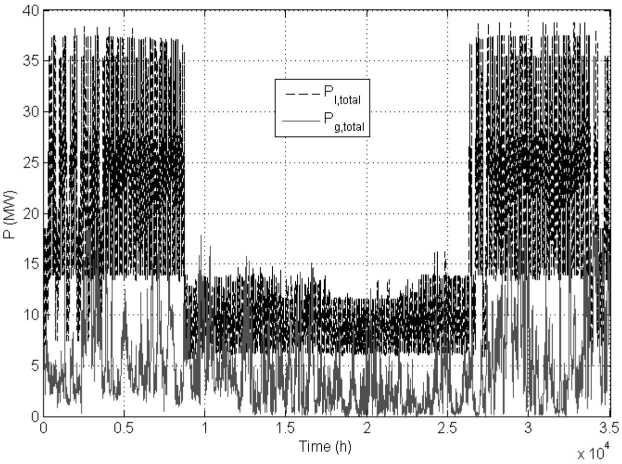

Figure 4: Total load and generation for the initial year

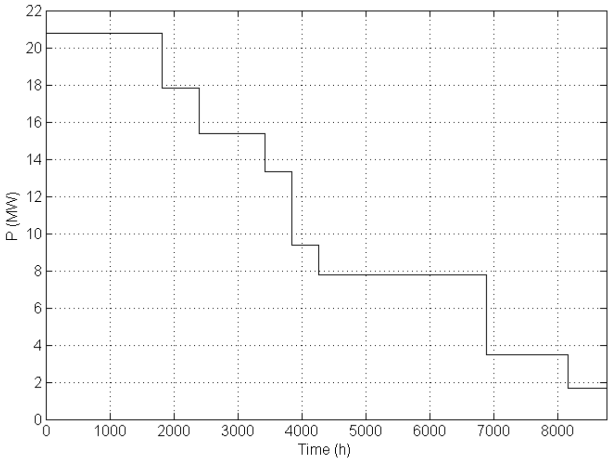

Figure 5: Injection duration curve approximated with eight representative days

The same representative days are used throughout the planning horizon. As noted earlier the method of [7] selects a pre-defined number of representative days and the use of eight days is found to be a good compromise between a better accuracy and an increase of computational burden of the procedure.

The system under consideration is rural, and voltage constraints are dominant. Consequently, firm generation connections are computed for minimal loading conditions, and a flexible range for maximum loading conditions. The results of GCAN computation are summarized in Table II.

Table II: Results of GCAN computations

Type	Generation connection (MW) FIRM	Generation connection (MW) FLEXIBLE
PV	9.65	17.25
Wind	18.30	31.72
CHP	7.45	13.95
TOTAL	**35.40**	**62.92**

The stopping criterion related to the LTC of the interconnection transformer is met for both the firm and the flexible generation computations.

40 substations are found to be sterilizing (the substations reducing the total connection amount) and their connection values are set to zero. The firm and flexible generation connections are obtained by separate runs of the GCAN procedure. The GCAN results are obtained after 14 iterations when computing the firm generation capacity and 16 iterations when computing flexible generation connections. When the system voltages are low (for maximum loading conditions), the procedure makes larger steps for incrementing the generations, according to the adaptive feature of the proposed repeated power flows [5]. The use of eight representative days to approximate weighted annual active power losses increases the number of power flow runs by four per GCAN computation step with respect to the procedure of [5].

The results show the considerable generation hosting capacity of the system. The capacity is mainly limited by the threshold set on the reversal power flow through the connection transformer. In order to illustrate this impact the threshold is varied between 50% and 100% of transformer nominal power. This is shown in Figure 6, where a saturation of the generation connection amount is observed. This is due to the system active power losses caused by the power flows over the networks.

Different publication formats of the GCAN results are considered within the GREDOR project [1]. Among the possible formats such as aggregation over the feeder, tabular presentations, GIS and other map forms of presentation, it appears that for the Walloon region of Belgium the most appropriate is a tabular presentation (a possible example is shown in Table III, with fictitious names for substations and feeders but real values for the system) and aggregation over the feeder (a possible example given in Table IV, with fictitious names for substations and feeders but real values for the considered system).

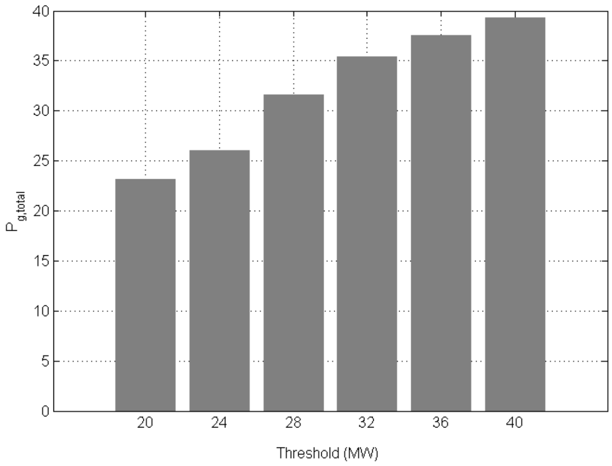

Figure 6: Impact of the threshold set on reversal power flow

Table III: A tabular presentation of GCAN results (made public by DSO)

Substat. name	Voltage (KV)	Upstream substation	Feeder	Gen. estimate (MW) FIRM	Gen estimate (MW) FLEX.
1	10	1-1	1-1-1	4.30 (Wind)	6.97 (Wind)
2	10	2-1	2-1-1	3.18 (PV)	4.45 (PV)

Table IV: An aggregation over the feeder presentation of GCAN results (made public by DSO)

Feeder	Voltage (KV)	Aggregated generation estimate (MW) FIRM	Aggregated generation estimate (MW) FLEX.
1-1-1	10	4.50 (Wind)	5.95 (Wind)
2-1-1	10	2.20 (PV)	3.15 (PV)

The presentation of the results is supposed to be published either by DSOs or through the regulator.

CONCLUSION

The GCAN procedure proposed in [5] is extended in this work by considering two practical constraints (limits imposed by LTC of connection transformer and reactive power flow into transmission network) as new stopping criteria. Furthermore, an approximation of annual losses using representative days is proposed. The extensions are validated using an updated model of a real life system. The extensions further confirm the flexibility of the GCAN procedure to incorporate any practical constraints. The procedure scales well with larger real life system. A better approximation of annual losses gives more accurate results while slightly increases the computational burden (it appears that the choice of six to 10 representative days is a good compromise). A tabular or aggregation over the feeder presentation form of the GCAN results appears to be two valid options for the considered region.

ACKNOWLEDGMENT

This research is supported by Public Service of Wallonia, Department of Energy and Sustainable Building, within the framework of the GREDOR project.

REFERENCES

[1] GREDOR (Gestion des Réseaux Electriques de Distribution Ouverts aux Renouvelables) project web site: gredor.be

[2] P.S. Georgilakis, N.D. Hatzargyriou, 2013, “Optimal distributed generation placement in power distribution networks: Models, methods, and future research,” *IEEE Transactions Power Systems,* vol. 28, 3420–3428

[3] European local electricity production deliverable 2.4, issue 1 2007, “Distributed generation ownership issues, review of current practices, future options and European policy recommendations”.

[4] Parlement Wallon, 2014, *Décret du 11 avril 2014 modifiant le décret du 12 avril 2001 relatif á l'organisation du marché régional de l'électricité et modifiant le décret du 19 décembre 2002 relatif á l'organisation du marché régional du gaz*, Parlement Wallon, Namur, Belgium.

[5] B. Cornélusse, D. Vangulick, M. Glavic, D. Ernst, 2015, “Global capacity announcement of electrical distribution systems: A pragmatic approach,” *Sustainable Energy, Grids and Networks,* vol. 4, 43-53.

[6] B. Cornélusse, D. Vangulick, M. Glavic, D. Ernst, 2015, “A process to address electricity distribution sector challenges: The GREDOR project approach,” *CIRED Conference and Exposition*, paper no. 0449, Lyon, France.

[7] K. Poncelet, H. Hoschle, E. Delarue, W. D’haeseleer, 2015, “Selecting representative days for investment planning models,” *TME Working paper – Energy and Environment*, KLU Leuven.

[8] S. Mathieu, DaysXtratcor, https://github.com/sebMathieu/daysxtractor

[9] R. D. Zimmerman, C. E. Murillo-Sánchez, R. J. Thomas, 2011, "MATPOWER: Steady-State Operations, Planning and Analysis Tools for Power Systems Research and Education," *IEEE Transactions on Power Systems*, vol. 26, 12-19.