REASONABILITY OF "FIT AND INFORM" FOR SOURCES UP TO 50 KW WITHIN LV NETWORKS

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ABSTRACT

This paper is devoted to the possible feasibility of amendment of #167 Directive of Europe Parliament and of the Council on the promotion of the use of energy from renewable sources [1] from December 6th 2017 (Subclause #17, Paragraph #1), stating the following: "Demonstration projects and installations with an electricity capacity of less than 50 kW shall be allowed to connect to the grid following a notification to the distribution system operator". Additionally, it discusses legislation aspects of connecting the generations to the distribution system in the Czech Republic in context of fit and inform procedure. The LV networks of the biggest DSO are analyzed regarding possible connection of 50 kW generation under existing conditions and considering planned LV network retrofit till 2040.

INTRODUCTION

In amendment of #167 Directive of European Parliament and of the Council on the promotion of the use of energy from renewable sources (reworked version) from 06.12.2017 is stated: "Demonstration projects and installations with an electricity capacity of less than 50 kW shall be allowed to connect to the grid following a notification to the distribution system operator ".
This approach would provide for easier connection of most newly connected sources within LV distribution system. Following table shows expected increase of installed power in LV networks in the Czech Republic distribution systems according to [8]:

Table 1: Installed power in LV networks

Year	2013 [MW]	2015 [MW]	2020 [MW]	2030 [MW]	2040 [MW]
Biomass	2	4	18	38	58
Biogas	3	6	16	24	32
Photovoltaics	289	433	561	1704	4001
Wind power	1	1	2	4	8
Microcogen.	4	61	303	607	910
Hydro power	64	67	72	73	74
Total	**363**	**572**	**972**	**2450**	**5083**

Significant increase of microgeneration and photovoltaics can be seen on this table. According to the document [8] the photovoltaics and microgeneration share of total installed power is 79 % and 18 % respectively. Following Figure 1 shows the share of power of individual generation types in the Czech Republic in 2040.

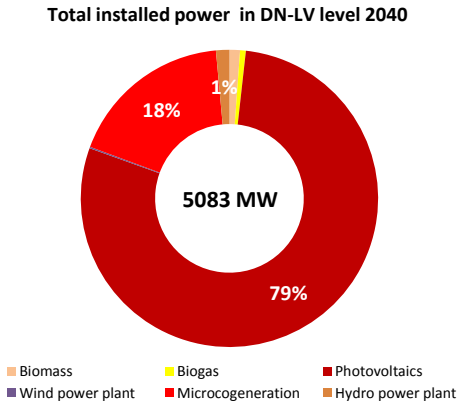

Figure 1: Expected share of power on LV networks in 2040, according to [8]

Keeping the power quality parameters (specifically the voltage magnitude and unbalance) and avoiding the network components overloading is the main issue of continuing resource integration into LV networks in the Czech Republic. These power quality parameters are stated in EN 50 160 [4].

Consequences resulting from valid standards

The "Fit and inform" procedure was used in the first edition of EN 50438 [2] stating that "fit and inform is recommended procedure for microgeneration installation excluding countries, where law prevents this approach to be applied, e.g. where DSO shall accept the connection first. Contrary, the amendment of this standard [3] includes different statement: "Foregoing acceptance by DSO is necessary unless otherwise is stated by national law or legislation". EN 50160 [4] is a key standard for power quality within Europe. This standard defines, describes and specifies main parameters of voltage at consumer feeders within public LV/MV/HV power network under normal operating conditions. Nevertheless, [4] does not define methodology for evaluation of planned generations and loads connection

impact, nor their acceptable level of contribution to allowed voltage variation and/or flicker etc.
Impact of LV network equipment with phase current ≤ 16 A (e.g. voltage variation, fluctuation and flicker), which is not subjected to conditional connection, shall be in compliance with IEC 61000-3-3 [6]. Such equipment can be connected to network without informing the DSO if the real network impedance at point of connection (POC) is lower than so called reference impedance (Zref). Simplified connection of microgeneration to the LV network is based on [6]. Thus 50 kW generation with phase current according to [6] shall not be connected provided that DSO was not informed. EMC parameters shall be in compliance with standard [7] that define allowed network impedance for specific equipment connection.

ASSESSMENT OF LV NETWORKS READINESS REGARDING THE 50 KW GENERATION FIT AND INFORM

Assessment of LV network readiness regarding the "Fit and Inform" in the Czech Republic was based on area consisting of about 50 000 LV networks supplying through 47 400 km of overhead lines and 56 320 km of cables 3 000 600 delivery points in given DSO. Area supplied by this DSO was described using 18 calculation model types taking existing state into account. Each model represents one specific distribution transformer station (DTS) type of total number of 48 070 DTSs.
Models were created according to the line type (overhead line, cable), line cross-sections, number of feeders in DTSs and number of inhabitants in supply area, forming following classification:

- ≤ 500 inhabitants (models 1 to 4)
- > 500 ≤ 5 000 inhabitants (models 5 to 8)
- > 5 000 ≤ 25 000 inhabitants (models 9 to 12)
- > 25 000 ≤ 50 000 inhabitants (models 13 to 15)
- > 50 000 ≤ 100 000 inhabitants (models 16 to17)
- 100 000 inhabitants (model 18)

Table 2: Specification of calculation models, actual state

Model number	Number of LV feeders in the model	Number of DTSs	Number of feeders in DNs
1	4	1353	5414
2	4	1805	7218
3	4	2707	10828
4	4	3158	12632
5	5	3331	16654
6	5	4441	22205
7	5	6662	33308
8	5	7772	38859
9	6	1834	11003
10	6	1834	11003
11	6	2292	13754
12	6	3209	19255
13	6	561	3365
14	6	785	4710
15	6	897	5383
16	7	1601	11207
17	7	1601	11207
18	6	2228	13368
Total		48070	251371

Figure 2 shows calculated impedance of feeders for each model representing existing state (models were calculated in DNCalc software).
These impedances were compared with reference impedance for three-phase connected equipment of up to 75 A (0.212 Ω) that is defined by [7] as reference impedance for this equipment, allowing their connection to the network without detail evaluation and without DSO agreement. Value 75 A corresponds with about 50 kW power at LV level.
Number of feeders not complying with reference impedance is calculated as number of non-complying

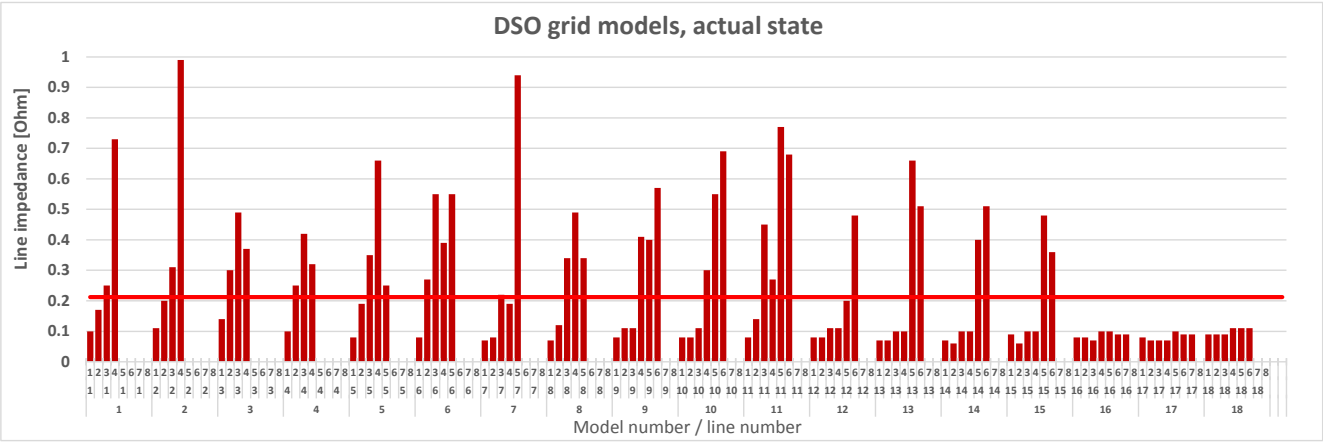

Figure 2: Line impedance of DSO grid models, actual state

feeders in individual modeled DTS multiplied by number of DTSs in given network model. Ratio of complying and non-complying feeders and DTSs can be seen on Figure 3. DTS was identified as complying if impedance at all its feeders was lower than reference impedance.

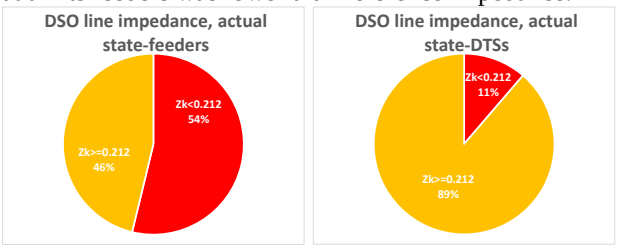

Figure 3: Ratio of complying and non-complying feeders and DTSs, actual state

The same number of models was created for the DSO's LV networks state predicted for 2040. These models take the expected network retrofit into account, which includes:

- shortening of line sections caused by increase of DTSs number (from present 48 070 to 62 959);
- Replacement of overhead line sections with highest impedance (small cross-sections) with lines of 120 mm^2 cross-section.

Table 3: Specification of calculation models

Model number	Number of LV feeders in the model	Number of DTSs	Number of feeders in DNs
1	4	1773	7091
2	4	2364	9455
3	4	3546	14183
4	4	4137	16547
5	5	4362	21812
6	5	5816	29082
7	5	8725	43623
8	5	10179	50894
9	6	2402	14411
10	6	2402	14411
11	6	3002	18014
12	6	4203	25219
13	6	735	4407
14	6	1028	6170
15	6	1175	7051
16	7	2098	14683
17	7	2098	14683
18	6	2916	17496
Total		62959	329229

Figure 4 shows the calculated impedance of feeders in each model for 2040. This calculated impedance is compared with reference impedance of 0.212 Ω. The same way as for present state was used for determining the future complying/non-complying feeders and DTSs ratio (see Figure 5).

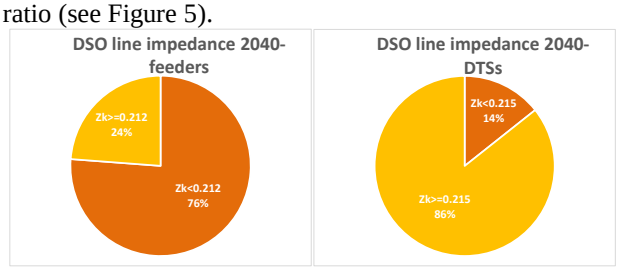

Figure 5: Ratio of complying and non-complying feeders and DTSs, 2040

As can be seen on Figure 3 and Figure 5, the number of feeders with impedance exceeding the reference impedance in 2040 is about half the number of such feeders in present (24 %, i.e. 78 355 LV feeders). The ratio of feeders with impedance exceeding reference impedance is 46 % in present scenario (i.e. 116 172). There are 42 640 DTSs (i.e. 89 %) in which impedance of at least one feeder exceeds the reference impedance at present state. Expected numbers for 2040 are 53 938 DTSs representing 86 %.

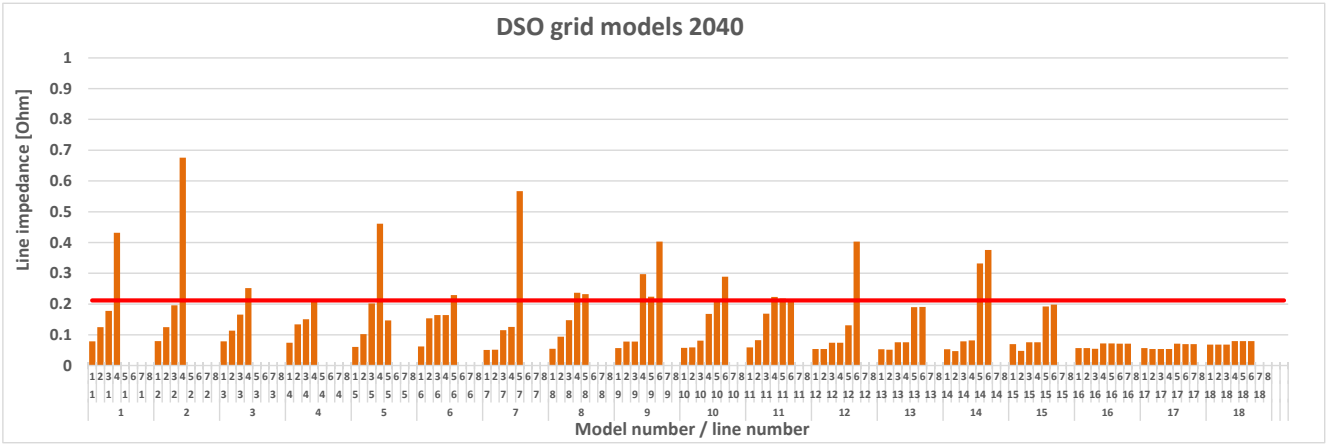

Figure 4: Line impedance of DSO grid models, 2040

Maximum generation connectible to the feeders

Additionally, the maximum power connectible to the worst impedance feeder was determine. Results can be seen at Figure 6. Voltage variation of 3 percent was the limiting factor for connection of generation as stated in [5]. Connectible power determination was provided for present LV networks state and for power factor of 1, which complies with valid legislation. Maximum connectible power generation caused by network retrofit increase of about tens of percent for 2040.

Alternatively, the maximum connectible power was determined for 2040 for lagging power factor of 0.9 and 0.95. This allows additional increase of maximum connectible generation power in order of tens percent at best for 2040. The impact of reactive power on lowering the voltage increase caused by generation is within tens of percent and up to 47 percent at power factor of 0.9 (model #17). Feeders contained in model #17 have lower R/X ratio at the end of the feeder in comparison with other models. Autonomous regulation with preset characteristics (Q=f(U), P=f(U), etc.) can be used to optimizing the voltage profile using reactive power.

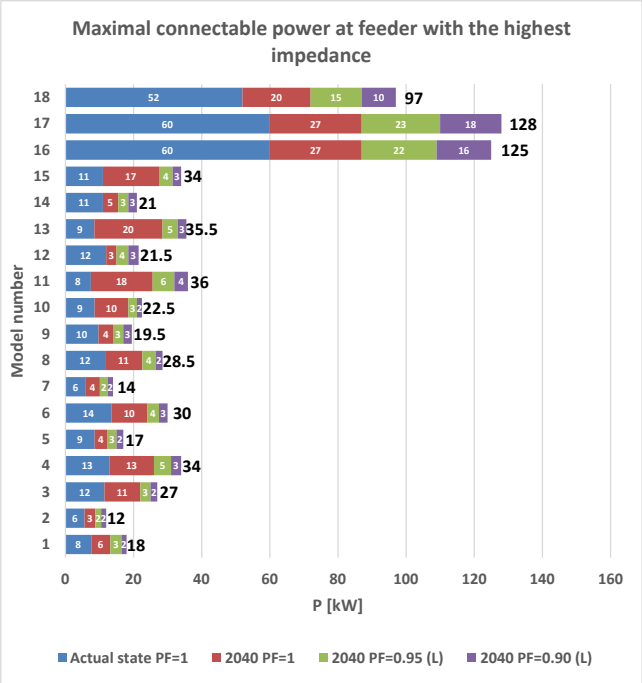

Figure 6: Maximum connectable power at feeders with the highest impedance, all variants

CONCLUSION

Based on the analyzation of LV networks of large DSO it can be clearly demonstrated that LV networks in the Czech Republic are not suitable for general application of fit and inform strategy for 50 kW generation. Analyzed LV networks contain feeders, which due their high impedance did not allow connection of 50 kW generation unit and keeping conditions specified in [5] at the same time. Analysis shows that planned network retrofit halves the ratio of feeders, which are not complying with reference impedance (0.212 Ω) to 24 percent, but the ratio of DTSs containing at least one feeder with impedance exceeding the reference impedance was decreased by 3 percentage points only (from 89% to 86%). According to the calculation of maximum power that can be connected to the feeder with highest impedance, only one 50 kW generation can be connected on fit and inform basis in the cities with more than 50 000 citizens. That represents some 35 782 LV feeders in service area in present and 46 861 LV feeders in 2040 (after retrofit), therefore about 14 percent of all LV feeders. Increase in required connectible power within LV networks can be supported by regulation of reactive power (e.g. autonomous Q=f(U) regulation). Efficiency of this regulation is lower in LV networks than on higher voltage levels. Moreover, reactive power flows in LV networks can increase the active losses in distribution networks.

Therefore, the general application of [1] is not feasible in LV networks in the Czech Republic, neither now or in near future. Fit and inform procedure cannot be used for 50 kW generation connection in most LV networks.

REFERENCES

[1] Directive of the European parliament and of the council on the promotion of the use of energy from renewable sources COM(2016) 767 final 2016/0382 (COD)

[2] EN 50438 December 2007: Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks

[3] EN 50438 December 2013 Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks

[4] EN 50160 Voltage characteristics of electricity supplied by public distribution networks

[5] D-A-CH-CZ Technical Rules for the Assessment of Network Disturbances, VEÖ, VSE, CSRES, VDN 2007

[6] IEC 61000-3-3:2013 Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current per phase and not subject to conditional connection

[7] EN 61000-3-11 Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection

[8] Ministry of Industry and Trade of Czech Republic, "National Action Plan for Smart Grids (NAP SG)," Praha, CZ, June 2015