ENTSO-E Advisory Council

Strategic advice on criteria to connect new generation to the grid

Context: Challenges in the allocation of connection capacity for generation

a. In the past, most generation units requesting a connection point to the grid had a single technology and firm connections to the grid, these units for the most part also had higher capacity factors than intermittent renewable generation, therefore using the maximum export capacity at the point of connection to the grid more frequently.

b. Nowadays, and in the future, intermittent renewable generation for the most part has a lower capacity factor, causing limited use of grid infrastructure in the vicinity of the renewable generator connection points.

- **Example 1.** A 1.0 MW wind farm with a 0.33 capacity factor will typically produce (8760*0.33 = 2890.8 MWh/yr), and a PV generator with a 0.11 capacity factor (8760*0.11= 963.6 MWh/yr). Both use a lower % of the maximum export capacity than a thermal generator (for instance, nuclear ~85% CP) (8760*0.85= 7446 MWh/yr). In high wind weather a wind farm exports 100% of its grid connection capacity, however over a year the overall use of the capacity is 33% of the time, as wind is not always blowing. Therefore, applying the same criteria in allocating connection capacity across renewables as was used in allocating connection capacity to hydro and thermal generators in the past, creates a locational underusage of grid infrastructure at these connection points and requires further up reinforcement of the grid.

- **Example 2.** If we want to reproduce the performance of a 100 MW thermal plant, we cannot do it with a 100 MW wind farm and storage, we will need more renewable capacity. Therefore, if we continue applying the current criteria to allocate connections to renewable generators the cost per MW/hr will be higher as the integration of 100MW will require the same grid infrastructure as a thermal generator with an 85% CP, however the MWh/yr production will be much lower.

- **Example 3.** The capacity at the connection point is not the only limiting factor, the available capacity will be influenced by the network in the vicinity of the node, other generators connected nearby, etc. When 50 MW of capacity is allocated to a specific generator at a given node, this uses up a proportion of the available network capacity for future generators at the same and possibly at other neighbour nodes. Increasing the connection capacity at nodes sometimes requires not only a reinforcement of the connection node itself, but of the network upstream. If wind and solar are connected to a node using the current criteria, there will be an underutilisation of the capacity at that node when the wind is not blowing or the sun is not shining, in comparison to connecting a thermal generator, and more infrastructure will have to be built in the area to inject the same amount of energy.

*Capacity Factor = (Energy Output /(Hours Per year*MW installed))

c. Until now, the allocation of connection capacity tries to ensure that the connected generator can inject its production into the grid without any restriction, i.e. the connection is firm. This makes sense when the generator can have a very large capacity factor such as thermal generation. However, securing this firmness for a variable generator such as a PV or wind generator will lead to significant unused connection capacity when the wind is not blowing or the sun is not shining.

- In general, criteria for allocation of connection capacity include setting limits on the peak capacity that can be connected to the grid, to ensure that the allocated connection capacity is not surpassed, maximum production is 100% of maximum export capacity.

- However, with technologies such as solar, wind and run-of-river hydro, it can make sense to install more peak generation capacity behind the connection point than the maximum export capacity allocated by the grid operator at a given connection point, i.e. there is a difference between the available connection capacity and the peak production capacity of the facility to be connected.

- In practice, this would mean that the grid operator/system operator should identify how much connection capacity is available in a given node while allowing the developer to size its facility to optimise their investment, installing >100% of its maximum export capacity behind the connection point, while guaranteeing that the export at the connection point never surpasses the agreed maximum export capacity.

- In many cases, this will mean a generation facility with an installed MW > 100% maximum export capacity would have to restrict its generation to 100% of the maximum export value at all times, as this is the connection design limit. It makes sense to give more flexibility to the generators to decide how best to make use of the allocated capacity.

- In some countries, such as Spain[1], Italy, France or Romania, this is restricted, and the developer is obliged to build a project with a maximum build out behind the connection point equal to 100% of the maximum export capacity, this does not allow for optimisation of the connection point. Restrictions are imposed by national regulation and European legislation is not detailed enough to prevent these regulatory limitations. The network code on connection of generation focus on a number of technical issues that the generator has to comply with (such as maintaining the operation within a given range of frequencies, resist certain types of fault in the grid, operation in island, deliver a range of reactive power, etc.), but does not deal with the connection allocation problem.

d. Giving flexibility to the generation developer when designing its facility can increase the utilization rate of the connection and grid infrastructure.

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[1] New legislation has recently been passed to remove these restrictions, but it has not yet been developed and applied.

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- If the connection capacity is 100 MW, the developer can choose to build a 100 MW wind farm, knowing that 66% of the time the capacity will be unused (if wind has a production capacity factor of 33% in that point. Alternatively, it can build a 130 MW wind farm to increase its capacity factor > 33%, knowing that the wind farm will have to curtail part of its 130 MW production capability in high wind situations down to the 100 MW maximum export capacity, however the connection point will obtain a better average utilization. In this way, if it has to pay for the connection capacity, it will bear a lower cost per MWh of production.

e. Beyond this, an additional solution could be based on "dynamic" or "flexible" connection rights (where the generator is allocated a certain amount of firm capacity and can expect a certain number of hours of additional non-firm connection capacity). Another possibility is the use of flexibility markets to deal with grid constraints: generators would bid changes to their production schedules to adapt them to the available capacity in each moment.

- Following with the previous example, this would allow the developer to use the full 130 MW part of the time, when authorized by the grid operator, when the grid is not constrained. In this way, more generation could fit into the same connection point.

- Not many countries offer this possibility for the time being. Obviously, the terms and conditions of these "dynamic" or "flexible" connection rights should be appropriately regulated, since it can be very difficult to agree for generators and grid operators, as shown, for instance, by the experience in Denmark.

- In any case, this should not lead to cross-subsidization of grid connection (some users paying more, to compensate for other users paying less). The benefit here is that the use of this approach would require less investment in grids, and therefore reduce costs for grid users and consumers.

f. At the same time, there will be an increasing number of more complex configurations, where different generation and/or storage technologies can be combined in hybrid facilities, leading to a higher use of the connection infrastructure.

- For instance, hydro, solar and wind capacity could be complementary when connected in the same node: when there is a lot of wind or sun and prices are lower, the hydro generation (unless it is run-of-river) would decide not to produce, and store added water inflow in reservoirs for a time without enough wind or sun. The wind and solar generators for the most part do not have such possibility of storage and thus have to produce whenever the wind or sun are available or stop producing, thus lose the opportunity to utilize the wind and solar influx for electricity production.

- If the connection point was studied at a 100% capacity factor, installing multiple technologies at the connection point, will increase the usage of that grid infrastructure, e.g. a wind farm 33% and a solar farm 11% capacity factor combined at the same connection point will use ~44% of the maximum export capacity in any one year. Therefore, the connection point is used to export

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electricity generation for more hours of the year (8760*0.44=3854.4 MWhr/yr), resulting in a higher capacity factor at that connection point and an overall lower cost of electricity production.

- If you also add a battery to this connection point, the usage of the grid infrastructure will again increase, the overall capacity factor at the connection point will increase, optimising the use of the local grid infrastructure.

- However, in some countries, the flexibility to combine different technologies in the same connection is restricted by regulation. For instance, requests for connection may have to be presented and assessed separately for each technology, leading to a suboptimal allocation.

- The criteria can be even more restrictive if the developer wants to combine existing assets (such as a hydro plant) with new assets (such as solar or wind generation, or storage) in the same connection, without increasing the maximum export capacity. In this case, it could even be required to re-apply for connection rights for all the assets in the node, even the “old” ones.

g. In this context, the assessment of grid connection capacity becomes more complex, slowing down the deployment of renewable generation.

- There is a compromise between using simplified procedures to determine and allocate connection capacity (which tend to be more conservative but facilitate the processing of large numbers of applications), and using more accurate studies, which can lead to a better allocation but slow down the analysis of connection applications. This is particularly the case if these studies have to be carried out by the grid operator.

h. Given the large amount of new intermittent renewable generation that is expected to be connected in the future, to fulfil EU climate targets/commitments, continuing to apply the traditional connection criteria could lead to significant over-investment in grid infrastructure that could have a relatively low level of utilization.

- Depending on the country, part of this additional infrastructure would typically be paid by the generators, leading to a higher development cost for renewables, while the rest would be part of the overall grid cost, paid by network users.

- An electricity system where most of the generation is variable, and where there are additional sources of flexibility, including storage and demand-side response, should find an efficient balance between investment in new grid capacity and curtailment of or storage of intermittent renewable generation.

i. Other challenges related to the connection of new generation to the grid refer to excessive technical requirements in the connection point (e.g. as in Austria, Belgium, Italy), grid charges (e.g. Denmark), lack of transparency on available and expected grid capacity (e.g. Sweden) and weakness of the grid in a number of countries.

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Advice

The problems mentioned here are related to national regulation and to the processes applied by TSOs and DSOs at national level. There is no clear path to a European solution, which would probably require additional legislation. However, the Advisory Council invites ENTSO-e to open a debate with its members and with the newly formed EU DSO entity on these issues, with the objectives of identifying and sharing best practices. The Advisory Council considers that these best practices should include the following:

- Generation developers should be given maximum flexibility to combine different technologies and size their plants, provided that there is a transparent process in place, while guaranteeing that the export at the connection point never surpasses the agreed maximum export capacity.

- Existing generators should be given flexibility to introduce hybrid configurations and modernize their plants to make a better use of the allocated connection capacity.

- Grid operators should make use of flexibility instruments to make optimum use of grid investments (the Advisory Council just issued an advice on this).

- Making use of more accurate criteria to allocate connection capacity without overloading the TSOs with new work, by allowing developers to present their own studies, based on methodologies approved by the TSO, and carried out by certified entities. Nevertheless, the final decision on capacity allocation should be taken by the grid operator.

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