Web consultation – Flexibility Resources: summary of the received feedbacks

Feedback was received from the following experts:

- Paul Hines – Packetized Energy
- Fernando Morales – Highview Power
- Mark Norton – Smart Wires
- Emil Hillberg - RISE and ISGAN Annex 6
- Ross Baldick – University of Texas (Austin)
- Tim Schittekatte - Florence School of Regulation
- Stamatios Chondrogiannis - JRC
- Hendrik Natemeyer - Amprion
- Evangelos Vrettos – Swissgrid
- Maja Božičević Vrhovčak – EIHP
- Michel Noussan – FEEM
- Qian Dai - China Electrical Power Research Institute
- Guillaume Renaud - SuperGrid Institute

Question 1 - Which conditions could be set to match technologies with nodes and establish limitations on the availability of a given node for a given technology, considering an automatic planning process?

Summary of received feedbacks:

Complementing the restriction areas presented in the table, the following **aspects are proposed for consideration**:

- **Environmental sensitive areas**: audible noise, risk of mineral oil spillage, ability to build lines, oil cooled cables, etc.
- **Accessibility**: e.g. weight prohibiting transport of a PST, HVDC, transformer, etc.
- **Availability of space**: e.g. residual space available in the substation. Some of the technologies have the possibility to be placed decentralized. That should be considered with regard to small space requirements.
- **Project lead time**: consider the time to put in place a certain solution, e.g. can a reinforcement be constructed in time or there is another shorter installation time viable source, e.g. Demand Response (DR)? HVDC or AC circuits often take over 10 years to develop ruling them out as viable solutions. Lead-times are only likely to increase in some areas, as best locations are taken first and areas become more congested environmentally.
- **Short circuit limitation**: would short circuit levels preclude new circuits or generation from being added as a solution (as these increase SC level)?
- **Congestion characteristics**:, e.g., duration.
- **Social acceptance**: this is one of the major barriers for network expansion and it may make more attractive the use of storage and DR options.
- **Technology restrictions**: restrictions are strongly related to the specific technology and other type of aspects could be considered, such as:
    - **Energy availability at the time of operation**: storage level (state of charge of the battery, reservoir water level…) and time of the day for flexible load availability.
    - **Ramping capability** of the flexible technology.
    - **Time to repair**: solutions should also include their availability, to ensure that the use of technology is impacted on decision making, i.e. a transformer that will take 12 months to replace/repair with 100% loss of capability is much different to a line that could be repaired in a day with 100% loss of capability; or demand response, which typically does not have a repair time and has a negligible loss of capability, but may only be a service offered for a portion of the year.
    - **Expansion capability**: if situations change, can the technology be resized or totally replaced? Some flexible technologies can manage uncertainty, allow the fine tuning of large scale projects' scope or works, and/or manage new network needs (new user connections/closures, changes in load demand usage, policy changes, etc.). PSTs and HVDC's cannot be easily resized and, hence, must be replaced or duplicated, if too small: their size is often set for 40 years and very much oversized in early years. Also, they can practically be used in a restricted range of sizes (high capital cost for small units, size and weight restrictions for large units). Other technologies do not have these restrictions and, hence, would give a totally different cost benefit analysis (CBA) performance, which needs to be modelled correctly.
    - **Operation conditions**: e.g. outdoor temperature for batteries, CAES, DR…

- In the case of **LAES**, systems with durations beyond six hours can be deployed. Therefore, the table showing congestion durations could show a green light for congestions beyond six hours. The longest system we have ever considered is about 10 hours.

Other aspects that have been mentioned are:

- The difficulty to perform this assessment in an automated manner.
- The availability rate of a resource at a node should not limit system performance. For example, a technology can be considered suitable, if its unavailability does not exceed a percentage (e.g. 0.1%) of the requirements.
- It might be worth representing the storage through screening curves and consider daily load duration curves.
- There might be certain overlap between “loads supplied” and “location of the bus” concepts in the table.
- Storage cannot be considered as a regulated asset because this is in contradiction with the EU energy directive.
- Some technologies have specific needs not related to the characteristics of the bus, e.g. pumped hydro. In this case, it should be much easier to mark the nodes where pumped hydro is possible instead of trying to determine the potential based on the bus characteristics.
- Hydrogen is a good choice for rural areas, with renewable energy production.
- Time series of historical locational prices (LMP) are a good proxy for the need for flexibility. Large volatility clearly indicates that storage of some sort could be useful. The frequency spectrum of the LMPs might actually be a good indicator of what type of storage would be useful. Higher frequency volatility might be a better fit for high efficiency, low time-duration solutions, like Li batteries and demand flexibility. Lower frequency volatility with frequency periods of negative LMPs would, probably, suggest the need for long-duration storage (where efficiency is less important).

Critical analysis:

Many aspects need to be taken into consideration to propose a flexibility technology for a certain location in order to relieve a congestion, among them: environmental restrictions, accessibility to the location, availability of space at the substation, project lead time, short circuit limitations at the network node, congestion duration, social acceptance of the project and others related to the technology itself, e.g. energy availability (storage level, DR), ramping capability, time to repair, expansion capability and operation conditions.

Most of these aspects are considered by the FlexPlan methodology, even if some of them might not be addressed at the flexibility candidate pre-selections stage. **Environmental restrictions** are considered in the “Restrictions” field, even if the reason of the restriction is not defined (it could be any of those mentioned above, including accessibility problems). If no information is provided for this field no restriction is considered, but there is one exception to this general rule, the resource availability data, if it is not specified that there is water available or that there are caverns available, hydro power and CAES are not considered as candidate by the tool.

The **availability of space** at the substation is considered through the “Type of bus” field (if the substation is underground, no solution can be integrated inside it) and the “location of bus” (if the area is urban more restrictions are present, mainly related to space availability).

Congestion duration is also considered: both the number of consecutive hours and the number of total annual hours.

The **social acceptance** is not considered because it is difficult to measure and difficult to relate to a node in particular, the impact could be translated to the project lead time. The **short circuit limitations** are not currently considered in the methodology, but it is an important parameter for new generation plants and lines.

Finally, the **project lead time** as well as the **technology related limitations** are something to be considered by the planning tool, which needs to choose among the best network expansion solutions considering all

their technical and economic characteristics. The candidates' pre-selection aims at reducing the number of grid expansion options, but it does not perform the final selection. Resource availability, ramping and time to repair are already considered in the methodology. Expansion capability and operation conditions are not considered. The planning tool performs a dispatching of the network resources (generators, storage, DR) and, therefore, aspects such as the available energy are considered for each simulation time step (both "type of bus" and "loads supplied" provide information about flexible loads).
Regarding the consideration of **storage as regulated asset**, FlexPlan does not consider the concept of ownership. However, in general, we consider that if the resource is necessary for the network, market mechanisms will push their installation, and if no market options are available, system operators will be allowed to instal and manage storage to operate the network safely.
We are considering both **Lagrange Multipliers** and **Locational Marginal Prices** for the identification of best locations to relieve congestions.
In the current methodology, the way to achieve an **automatic planning process** considering these inputs is to use heuristic rules that permit to pre-select the candidates. The aim is to reduce the size of the optimization problem but, at the same time, not to interfere on the optimization by missing a suitable solutions.

Question 2 - Would you propose a very different approach to the one presented here?

Summary of received feedbacks:
In general, **the approach seems to be valid** (6 responses). To support this, one response highlights that the system operator needs to consider a trade-off between lines and flexibility in planning. Thus, the potential of flexibility needs to be estimated at all relevant locations. To do this, the system operator needs to have some ideas of which technologies can be expected and the different technologies are a function of the specific characteristics of the node. However, in the procurement of the flexibility the system operator shall be technology-agnostic. One advantage is that congestion, and other system issues, can be solved in many ways, i.e. in most cases there would be different sets of nodes, each with their own flexibility potential, to solve one specific local issue.

Nevertheless, some **aspects for improvement** are proposed:

- A missing element is the newly introduced EU legal requirement to **maximize the existing use of networks**, plants and equipment before considering adding new substations and/or lines. Therefore, technologies able to fit into existing stations, not requiring new developments, or services that can be provided by users should be the first solutions considered and, only if these do not deliver, look to expand with new circuits or stations.
- **Voltage related issues** should be considered also during the investment planning process. Voltage restrictions may arise in scenarios other than congestion, and one solution may solve both issues if duly considered. One alternative approach would be:
    - Quantify the amount of active/reactive power (or energy) provided from a certain bus required to mitigate the congestion
    - Provide a list of investment costs (cost/MW), depending on the technology, that solve the issue.
    - Evaluate the feasibility of different investments.
- The **state of charge** of the battery and related constraints should be represented (the screening curve approach could be a way to do this). Representing many individual storage resources is not tractable, at least not "from scratch." An alternative, at least for a first cut, is to first amalgamate all storage at one bus (even though there are binding transmission constraints) and then, second, come up with an initial dispatch of the storage that can then, third, be allocated out to individual storage devices as a "warm start" for any optimization. Depending on the level of required

accuracy, one might even just do the first two steps without the explicit allocation to actual storage locations.

- It is highly recommended to add the option **investment candidates and locations to be defined manually by the user**. Network operators use their accumulated expert judgement to make network expansion decisions, and it is very debatable if they abandon this approach for an untested automatic one. Moreover, it is debatable if an algorithm can encompass all issues considered practically for network expansion decisions (e.g. what about social acceptance?).The automatic process could provide significant value as an additional tool for the planner to identify network expansion options, i.e., as an additional input to its expert judgment process.
- **Dynamic Line Rating** (DLR) and **Static Synchronous Series Compensators** (SSSC) are also able to provide flexibility to the network and they should be considered as options together with PST, HVDC and grid balancing batteries. Any or all of these should be assumed to be operated in real time in the future but reflecting the physical characteristics of the devices i.e. maximum/minimum practical unit size, speed, aggregated losses, tapping range and total number of taps that can be used before maintenance for a PST; and for an HVDC, maximum/minimum practical unit size speed, ramp rate, aggregated losses, range, commutation failure, etc.
- **A set of storage systems** can be located across bus bars with network constraints **to modify power flows (virtual lines)**, reducing the intensity of these and supporting synchronicity. This would require a planning and operational tool focused on storage which is not available now.
- To address dropping levels of inertia and short circuit level, **synchronous condensers** are proposed as solution, even if they can be exposed to oscillatory behaviour when they carry high power flows, in long lines. They might not result in the lowest cost to the end consumer and they delay the utilization of storage.
- Different equipment provides various **additional values to the grid** (other than solving the congestion at hand). These values should also be considered in order to have a fair evaluation of alternatives. In the UK, we see that flexibility assets are being proposed to solve renewable curtailment issues, peak demand issues, voltage issues and, now, grid operators are also aware of the need to ensure certain levels of system stability services at locational level. Indeed, National Grid is producing effectiveness maps showing the nodes where there are problems related to short circuit level, synchronous inertia and dynamic reactive power.
- The previous **effectiveness maps** are used by potential solution developers to identify the most attractive nodes in the network to connect their solutions. It is not clear if the proposed approach would also integrate network constraints such as stability requirements or restoration requirements that could be served by flexibility options. In the case of energy storage, it would be paramount to be able to monetise temporal and locational value created when connected to specific nodes in the network.
- Acknowledging the value that storage can bring when it comes to, for example, inertia or providing other network services. When entering storage in the tool, a **net CAPEX** can be considered, defined as a gross CAPEX minus revenue from system and capacity payments. If this is not acknowledged, the model will never select storage, especially, at current prices that still include first of a kind costs for storage.

Critical analysis:

The aspects for improvement can be classified in the following groups:

- Those **addressing the current approach of the planning methodology**: maximizing the current use of the networks is implicitly considered in the planning process since a minimization of costs is performed, so using an existing assets should be always more cost-effective than making a new investment. The state of charge of storage and its characteristics are also considered by the planning tool, which performs an hourly dispatch of the whole system. The option of proposing candidates by the user is done partially, just for those cases where new lines want to be proposed to link substations that are not connected in the reference case. The voltage and reactive power

issues are not considered to select congestion scenarios, however, the current methodology based on Lagrange Multipliers and LMP could be adapted to do so.
- Those proposing **new flexibility resources**: technologies or approaches such as the DLR, SSSC, virtual lines (including storage at both ends of a line) and synchronous condensers, are prosed. DLR is not considered, since no temperature variable is included as parameter. SSSC and synchronous condensers are not considered, the only technologies permitting to vary the power flow in a line are PSTs and HVDC. Virtual lines based on storage solutions could be considered when the two storage candidates are proposed at the end of a network branch, but then the planning tool should decide if the optimum solution is to use none of them, one, or both of them.
- Those proposing to **consider the benefits of service stacking for storage**: this is not currently considered. The CAPEX of the storage does not include a reduction due to possible incomes by providing additional services to the system. The problem here would be to provide a number for those incomes associated to network services. There are many uncertainties linked to this: evolution of markets at EU level considering national specifics, know which services will be provided through the market and which will be requested in connection codes without revenue, provide a yearly revenue value for the timeframe 2030-2040-2050, etc. In addition, in FlexPlan we are not modelling the network in timeframes below one hour and this makes that we cannot perform this calculation in an asset dispatching framework.

Question 3 - Do you think that we could use the available characterization information for other tasks within the planning process, not considered in the presented methodology?

Summary of received feedbacks:

According to one of the responses, this characterization information cannot be used for other tasks within the planning process. However, some **proposals to use this information** are provided by other respondents:

- **Subsea cabling** will require distance to determine between AC or DC links, also spanning water bodies (rivers/lakes) will be required to define if OHL viable.
- **Time to construct** should be used to ensure the cost saving of either more years of benefits or deferred capital investment.
- **Relocation** is required to be able to move some applicable technologies (must include time to move) to a better (more beneficial) location.
- One item in the planning process is related to the **public resistance to investments** (NIMBY). Possibly the characterization of buses/areas could be used to assess the risk of delayed investments due to public issues, which is a valuable parameter to consider.
- Asses the **risk of outages** or other issues for which the probability might be conditional upon the characterization.
- The **risk for power market issues in the procurement**, i.e. there might be a flexible alternative to grid expansion but maybe not enough space for real competition.
- The **duration of assets**, such as DR and Storage is key in determining their contribution to security of supply. In addition, the characterization of traditional reinforcement as underground or overground can be used to compare different solutions economically. Additional nodal characterization could qualitatively capture voltage, stability and restauration scarcities.

One general comment is that the characterization information made available by this method seems to be able to give good indications for other tasks of the planning process. However, this information is obtained within a specific framework and it is necessary to make sure that the framework of the other tasks corresponds to the same hypotheses.

Critical analysis:
The information for bus characterization can be used for other purposes, however, some of the proposals are **hard to match with the current methodology** adopted in the project, since the specific data is not considered: time to construct, relocation, public resistance and risk for power market issues.
Other aspects are already considered, such as: the routing of cables between two substations considering geographical characteristics and different technologies (AC/DC, overhead/underground), the risk of outages (even if the probability does not depend currently on bus characteristics) and the duration of assets, which is one of their defining characteristics.

Question 4 - How could be assessed the impact of landscape factors on new infrastructures costs?

Summary of received feedbacks:

The geography will have an important impact on costs. Some aspects to be considered related to the **landscape impact on new infrastructures cost are the following**:

- The impact will be important in locations with transmission and distribution constraints and large amounts of wind/solar. Looking at the cost of land, wind/solar resource and comparing to transmission availability could be useful.
- **Environmental aspects** need to be considered: areas of outstanding beauty, special areas of conservation, protected views, noise restrictions…
- **Accessibility** (the difficulty of transportation) and the **difficulty of installation** have influence on costs: roads or bridges that do not allow heavy or big size equipment, rail connection…
- Necessity to build a **tunnel** in an urban area, i.e. 5 times the cost of open countryside.
- Some countries have defined **limits to the length of EHV cables** due to technical reasons, e.g. no longer than 10km at 400kV, and the system operator's own analysis would be that there is a 'budget' of cable (due to its capacitive/resonance effects) that a system, as a whole, can accept before presenting a unacceptable high risk to the network.
- In general, the more urbanized the more difficult. Aspects to be considered: altitude, pollution, icing, etc. It could be useful to **use a multiplier per landscape type**, e.g. plain: 1; hilly: 1.2; etc.
- The analysis of past **experience**/projects and expert judgment by network operators is essential.
- Not only topography, but also **local opposition** should be considered.
- Perhaps, a **PESTEL analysis** could be used to perform a qualitative analysis or landscape impact could be presented as potential barrier. Otherwise, by creating an **adjusting factor** depending on the severity of the impact. For example, taking into account two extremes and calibrating these factors with these extremes, e.g. a short LV cable against a country wide EHV power line. It is not clear how to attribute a monetary value to this aspect.

Critical analysis:
The impact of landscape factors on the cost of new infrastructures might be relevant: meeting environmental requirements, the accessibility and characteristics of the location that may make the installation difficult, the necessity to build tunnels, urban areas in general, etc. Local opposition might be an indirect aspect that increases costs.
To use **factors** that increase the cost of the solutions depending on the severity of the impact of landscape might be a way to consider their influence in the study.