Smart TSO-DSO interaction schemes, market architectures and ICT Solutions for the integration of ancillary services from demand side management and distributed generation

Ideas and alternatives for the cost-benefit analysis performance

Document for consultation

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1 Cost-benefit analysis (CBA) of the different schemes

With the results obtained from the simulations, one of the main goals is the elaboration of a CBA methodology for the analysis of TSO-DSO interaction schemes[1] and the assessment of the best TSO-DSO interaction for each national case. With that purpose, next steps will be followed:

1) Development of a CBA procedure:
   - State of the art of metrics for CBA.
   - Selection of SmartNet metrics.
2) Macro-level CBA (at system level):
   - Calculation of values for metrics with the data input from the simulations.
   - Once the metrics have a value, that value needs to be monetised.
   - Cost calculation of the required information and communication technologies (ICTs).
   - Evaluation of every coordination scheme in all countries.
3) Micro-level CBA (at business case level):
   - Identification of the value chain.
   - Allocation of costs and benefits per stakeholder.
   - Sensitivity analysis.

The objective of the micro-level analysis is to define a business scenario which allows all the involved actors to have a profitable business case. Therefore, it aims at properly allocating costs and benefits to the different stakeholders. Since the details for the micro-level analysis are not sufficiently developed for a consultation yet, this consultation is oriented to help guide the process to perform the macro-level CBA.

1.1 CBA methodology – Literature review

Several methodologies have been reviewed in order to determine their applicability to the SmartNet analysis. The analysis included:

- **Electric Power Research Institute method** (available at: https://www.epri.com/#/pages/product/000000000001020342/)
- **Joint Research Centre methodology** (available at: https://ses.jrc.ec.europa.eu/sites/ses/files/documents/guidelines_for_conducting_a_cost-benefit_analysis_of_smart_grid_projects.pdf)
- **International Smart Grid Action Network method** (available at: http://www.sasgi.org.za/wp-content/uploads/2.21_ISGAN_Annex3_-Issue2.0_28Sept2011.pdf)

[1] Basics for coordination schemes and market design are available at: http://smartnet-project.eu/wp-content/uploads/2017/06/2-SmartNet-PowerTech-20170619-TSO-DSO-CS-Six-V2.pptx and http://smartnet-project.eu/wp-content/uploads/2017/06/3-20170619_SmartNet-G.Leclercq-Presentation-VF.pptx.

- **Pacific Northwest National Laboratory method** (available at: http://epe.pnnl.gov/capabilities/cba.stm)
- **U.S. Department Of Energy/Federal Energy Regulatory Commission method** (available at: http://www.synapse-energy.com/sites/default/files/SynapseReport.2013-02.LBL_.DR-Cost-Effectiveness.11-106A.pdf)
- **REALISEGRID project** (available at: http://realisegrid.rse-web.it/content/files/File/Publications%20and%20results/Deliverable_REALISEGRID_3.3.1.pdf)
- **e-Highway 2050 project** (available at: http://www.gridinnovation-on-line.eu/Articles/Library/E-Highway-2050-A-New-Multi-Criteria-Cost-Benefit-Methodology-To-Compare-New-Transmission-Investments.kl)

The analysis of further CBA methods continues in parallel to this consultation.

1.2 Macro level CBA analysis

The evaluation of different investment alternatives needs to define:

- A set of criteria (metrics). They need to be complete, non-overlapping, applicable, system-oriented, simple, reproducible, documentable, realistic and objective.
- A set of weights that establish the importance of those metrics.

The definition of metrics is a very critical issue, but the assignment of weights to them is even more critical and controversial.

Two approaches exist for the assessment of the alternatives:

1) The multi-criteria analysis approach consists in; defining a set of criteria for classifying alternative investment variants, providing quantitative indicators to quantify the selected criteria, converting indicators into one only utility value (possibly a-dimensional), performing a weighed linear combination of utility values (weights incorporate the importance of the different criteria).

2) The cost-benefit analysis approach. It tries to reduce the problem complexity by converting all indicators into a monetary unit (no need to assign weights as such, but just converting all the metrics into money). In SmartNet, we opted for this approach, since it allows a more straightforward comparison between the different alternatives and, for some metrics, the monetisation process (CBA) is more objective than assigning subjective weights (multi-criteria).

In the macro analysis each coordination scheme will be assessed for Denmark, Italy and Spain and the results compared against a baseline. The definition of this baseline is one of the questions included in this consultation. Metrics will be elaborated and applied for comparing the TSO-DSO interaction schemes for each national case and, as result, the different schemes will be independently scored for each country. Then, the most convenient architecture, different for each national case, will be highlighted.

Figure 1 shows the macro analysis synthesis, in which it can be seen that the ICT costs related to the coordination schemes will be managed separately from the rest of the costs directly linked to the coordination schemes deployment. The procedure for the ICT costs estimation is detailed in Section 1.3.

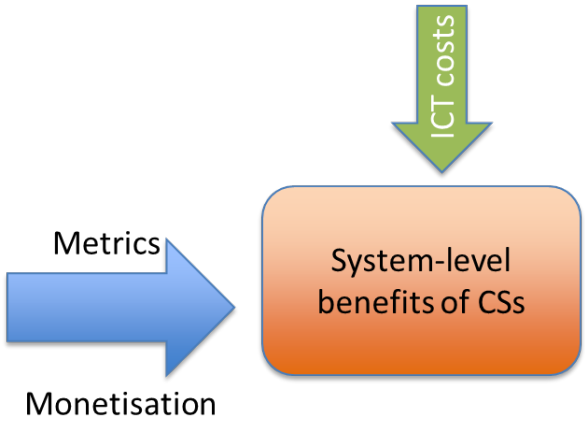

Figure 1: Macro analysis synthesis

In general, the metrics may be divided into three categories[2]:

1) **Core elements:** Typical CBA ingredients, e.g. lifecycle costs, overall system social welfare, CO_2 emissions, system reliability, etc.
2) **Experimental items:** Innovative items or elements difficult to assess, e.g. extra costs due to distribution investments, extra costs due to market power, socio-environmental costs of new lines, etc.
3) **Sensitivity factors**: Extra elements to enrich decision maker's knowledge, e.g. social welfare split, renewable energy sources (RES) curtailment costs, etc.

The main proposed metrics to quantify the costs and benefits of the different SmartNet coordination schemes are:

a. **Enhanced provision of ancillary services**: The TSO-DSO coordination schemes investigated in SmartNet are aimed at increasing the competitiveness of ancillary service provision, by extending their related markets to distribution energy resources (DER), i.e. where the centre of mass of power flexibility is expected to be in a near future. In particular, SmartNet simulations will be focused on the real-time market devoted to the activation of the flexible DER for the energy balance of the system (manual Frequency Restoration Reserve –mFRR– and Replacement Reserve –RR– depending on the country) taking into account also the network limitations (congestion management). The proposed metric to evaluate this aspect is balancing cost[3], which can be monetised by multiplying the cleared balancing cost and the activated volume..
b. **Cost attributable to network limitations:** The real-time market simulated in SmartNet takes into account complete network models and it guarantees that the final activations are selected in order to avoid (voltage and loading) congestions and to keep energy

[2] As defined in http://www.e-highway2050.eu/fileadmin/documents/Results/D6.1_A_comprehensive_long_term_benefit_cost_assessment.pdf

[3] We think that social welfare is not a suitable metrics because there could be cases when an arbitrage between bids could get a better social welfare but we have instead only to minimize the cost to activate resources to solve congestion and imbalance (optimizing social welfare is the aim of the previous energy markets).

losses limited. Depending on the TSO-DSO coordination scheme, the market effectiveness in taking into account network limitations is expected to be different and, consequently, the activated resources as well (with a direct impact on the cleared balancing price). Network operators are carefully considering the occurrence/severity of congestions and losses in order to evaluate grid refurbishment actions which, in turn, are inversely proportional to the effectiveness of the market in solving undesired situations. This effectiveness can be evaluated by comparing the cleared balancing price of the following two situations:

- Real situation, in which the entire physics of the network (losses, transmission capacity) is simulated.
- Ideal situation (busbar simulation), in which electricity network is simulated disregarding the physics and with zero losses.

It is immediate to deduce that the price difference between these two situations corresponds to the cost attributable to congestion management and to network losses compensation (an intermediate situation could be performing a copperplate simulation, where the electricity networks have infinite transmission capacity, but network losses are taken into account, so that only the cost of congestion management could be derived from the price difference). This difference also directly returns a monetary value and it is a valuable indicator for the profitability evaluation of refurbishment investments[4].

c. **Reduction of unwanted measures adopted by network operators in order to solve congestions:** As anticipated above, the real-time market simulated in SmartNet includes the network models and limits. Depending on the TSO-DSO coordination scheme, this model is limited to transmission network or extended to distribution too. In addition, the market architecture impacts on the ability of the market operator in predicting network congestions and to consequently activate the right resources to avoid them. Having considered that the simulated coordination schemes are expected to solve congestions with different effectiveness, network operators will inevitably deal with some critical situations (unexpected congestions) to be immediately solved with dedicated (unwanted) measures, such as:
   - Immediate curtailment of load/generation.
   - Blocking of activation signals.
   - Inhibition of bidding of non-prequalified resources.

   Even in this case, the monetization of the unwanted measures can be easily performed. In particular, since these actions inevitably cause an imbalance in the system, a good indicator can be represented by the consequent imbalance price. However, when it does not represent the price to activate curtailment, the compulsory limitation of flexibility can be evaluated according to the associated resource costs.

d. **Reduced network losses**: Because of the non-ideal behaviour of network components, energy losses are an unavoidable element of power systems and it may have a significant impact on the management of both transmission and distribution grids. Taking into account the market architectures investigated within SmartNet, there is a concrete potential of reducing energy losses by approaching supply and demand of

[4] A detailed analysis should consider the situation after each grid refurbishment investment, so that the economically sound refurbishments would be identified (there may be some bottlenecks which only appear in very extreme situations and, hence, whose removal would not be economically efficient), but it is not the aim of this analysis to be so detailed.

ancillary services. The proposed CBA will compare the effects of each TSO-DSO coordination scheme on the energy losses by processing the simulation results. Their associated cost can be calculated by integrating them with the energy price profile (resulting from the market). Thanks to this integration, the CBA will also consider the coordination scheme ability of selecting the optimal energy paths depending on the current price of energy.

e. **Emissions savings**: A more efficient cooperation between TSOs and DSOs, together with the integration of network/resources models in the market clearing algorithms, is expected to be beneficial in the optimal management of available flexibility, including the one provided by low-carbon generation technologies (which are gradually replacing conventional plants with higher carbon emissions). Generation dispatch and unit commitment model is used for calculation of emissions savings in each coordination scheme compared to the reference scheme. Standard emission rates for each generation technology will be taken into account.

   The monetization of CO_2 costs is based on forecasted CO_2 prices for electricity in the studied horizon. The price can be derived from official sources such as the International Energy Agency.

1.3 ICT costs

The term ICT cost comprises the communications and information technologies, including the software for the market clearing process. Only those ICT costs that are directly related to the implementation of a coordination scheme will be considered. The main goals of this estimation are:

- To discover differences between coordination schemes in terms of ICT.
- To analyse requirements of ICT systems (market arrangement system and bidding system), the amount of communication, and its requirements in the coordination scheme.
- To estimate the ICT costs (in 2030) in each national case and coordination scheme.

For the definition of the ICT costs the following steps will be carried out:

1) Functionalities definition (e. g. data handling, security, reliability, etc.). Comparison of the coordination schemes in terms of functionalities in its ICT systems.
2) Convert each ICT system in a coordination scheme into a current cost. Estimation of ICT system cost development from current costs to year 2030.

This ICT estimation involves large uncertainties on technology and cost development since the details of year 2030 are currently unknown. The main focus of the analysis will be on issues that can make differences between coordination schemes.

The systems and communications not directly related to coordination schemes are left outside the scope of this analysis, and the use of existing communication for low capacity traffic will be assumed to be free.