DEFINITION AND PRACTICAL APPLICATION OF KEY PERFORMANCE INDICATORS TO SUPPORT EUROPEAN GRID OPERATORS TO ENABLE THE ENERGY POLICY GOALS

Gareth BISSELL, Carlos COSTA
Enel Distribuzione SpA – Italy
Garethrobert.bissell@enel.com
Carlosfrancisco.costarausa@enel.com

Michele DE NIGRIS, Ilaria LOSA
RSE – Italy
Michele.DeNigris@rse-web.it
Ilaria.Losa@rse-web.it

Massimiliano MARGARONE
T&D Europe - Italy
massimiliano.margarone@gmail.com

Thong VU VAN
ENTSO-E – Belgium
thong.vu.van@entsoe.eu

Serge GALANT
TECNOFI – France
SGalant@symple.eu

Jesus VARELA
Iberdrola - Spain
jvsa@iberdrola.es

Prof. Marco INVERNIZZI
University of Genoa – Italy
53485@unige.it

ABSTRACT

Key Performance Indicators (KPIs) were developed by the GRID+ project to monitor the contribution of each single innovation project to achieving the specific objectives of the European Electricity Grid Initiative (EEGI) R&I Roadmap 2013-2022 [1] (EEGI Roadmap). These KPIs will help policy makers, regulators and network operators in using the results of R&I activities to prepare decisions for the large scale deployment of innovative network solutions that have been demonstrated thanks to the EEGI Roadmap activities and promising scalability and replication replicability prospects of the project results.

A framework is based on two categories of KPIs: Implementation effectiveness KPIs, which measures the completion of the EEGI R&I Roadmap; and Expected Impact KPIs, which these will measure the benefits achieved by European R&I projects and are split into three levels: Overarching, Specific and Project KPIs. The monitoring of these KPIs will help preparing the deployment of promising network innovations as demonstrated by the EEGI activities together with national regulatory bodies, that are supported by proper scalability and replicability studies.

INTRODUCTION

In order to meet the European energy and climate change targets for 2020 and beyond the European electrical transmission and distribution systems must be modernized to enable a cost-effective deployment of low-carbon energy technologies, as proposed in the (Strategic Energy Technologies Plan) SET Plan.

The EEGI is one of the European Industrial Initiatives under the SET Plan and proposed a nine year European research, development and demonstration (RD&D) programme to accelerate innovation and the development of the electricity networks.

Funded by the European Seventh Framework Programme (FP7), the GRID+ project coordinates and supports developments and progress towards meeting the goals of the EEGI. KPIs defined within the GRID+ project [2] will be used to monitor the progress of European and nationally funded R&I (Research and Innovation) projects towards reaching the objectives defined within the EEGI Roadmap.

The EEGI Roadmap describes 34 Functional Objectives that represent the challenges that need to be addressed by R&I actions. These Functional Objectives are grouped together as innovation clusters that represent common areas of activity. Within the EEGI Roadmap there are three sets of innovation clusters for TSO, DSO and joint TSO and DSO activities.

A reduced set of KPIs have been produced that will represent the overall objectives of the R&I activities described in the EEGI Roadmap. Two categories of KPIs were defined:

- Implementation effectiveness KPIs
- Expected impact KPIs

IMPLEMENTATION EFFECTIVENESS KPIS

The Implementation Effectiveness KPIs will measure the progress of research and innovation activities, as a percentage of completion of a functional objective or a set of functional objectives within any of the clusters defined in the EEGI Roadmap. The implementation effectiveness for each Innovation Cluster as defined in the EEGI Roadmap will be evaluated based on the current investment with respect to the allocated budget. The methodology includes the evaluation of activities that are:

- Completed
- Ongoing
- Under proposal
- Not yet started

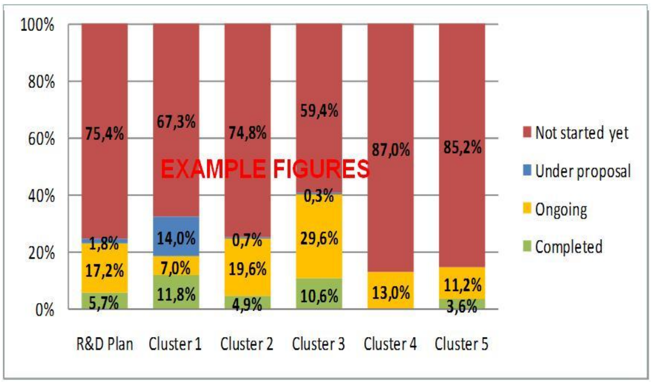

Figure 1 Implementation Effectiveness Indicator

EXPECTED IMPACT KPIS

The Expected Impact KPIs are structured into three levels which follow a top down approach. The overall ambition of the EEGI is represented by the 'Overarching KPIs'. These consist of a limited set of network and system performance indicators which trace clear progress brought by EEGI activities towards its overarching goal. They are intended to provide a very high level understanding of the benefits that would be achieved by European R&I projects and will be evaluated at a system level. Two overarching KPIs were defined and these are:

- Increased network capacity at affordable cost
- Increased system flexibility at affordable cost

Next there are 'Specific KPIs' that provide measures that determine the progress of several technical parameters relevant for network operators in order to reliably achieve their overarching goals within the different Innovation Clusters and Functional Objectives of the EEGI Roadmap. These indicators will be evaluated using a methodology based on the replicability and scalability of the aggregated results from European and national R&I projects. Seven 'Specific' KPIs were defined and these are as follows:

- Increased RES and DER hosting capacity
- Reduced energy curtailment of RES and DER
- Power quality and quality of supply
- Extended asset life time
- Increased flexibility from energy players
- Improved competitiveness of the electricity market
- Increased hosting capacity for electric vehicles (EVs) and other new loads

The results of individual projects will be represented by their own KPIs that are defined within the project and these are referenced to as 'Project KPIs'.

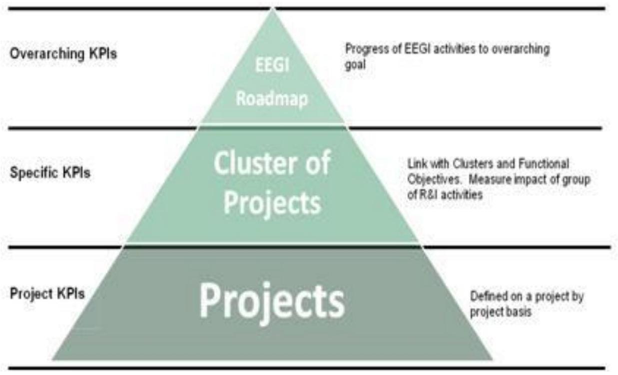

Figure 2 EEGI KPI developed framework for expected impact KPIs

For each 'Specific' KPI there are two methodologies defined:

1. Ex-post methodology using field measurements and appropriate scalability up and replicability studies for deployment scenarios.

2. Ex-ante methodology based on studies such as simulation test bed developed by T&D Europe [3]

For both ex-post and ex-ante methodologies the objectives are to quantify the impacts delivered by the R&I project, as graphically represented in Figure 3, requires therefore to compare what would be the expected benefits from applying a R&I solution versus the expected benefits of applying a BAU solution as a reference. This will highlight the possible contribution of the EEGI Roadmap to achieve the European Union energy policy goals.

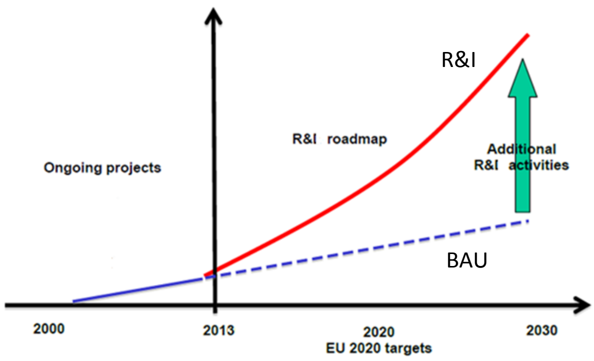

Figure 3 Expected benefits of R&I activities with respect to BAU

INCREASED RES AND DER HOSTING CAPACITY EXAMPLE

As an example, the definition and approach for calculating one of the 'Specific' KPIs will be described in this section. Increasing RES and DER hosting capacity is increasingly becoming a challenge that is facing European DSOs. It is also one of the expected benefits from the implementation of active distribution system management on DSO networks.

Increased RES and DER Hosting Capacity KPI Definition

The transition towards decarbonisation stimulates higher and higher integration of RES and DER. The contribution to achieve energy policy and climate goals the transmission and distribution grids must ensure sufficient capacities to host reliably RES and DER. To increase the amount (expressed in GW or MW) of RES/DER integration by intelligent network investment, using advance power technologies or better coordination of system operation. To give a statement about the additional RES/DER that can be installed in the network thanks to R&I solutions compared to BAU of conventional reinforcements (i.e. new grid lines).

The RES/DER hosting capacity is the total installed capacity of RES/DER that can be connected without endangering system stability and reducing system reliability. RES refers to large wind, photovoltaic (PV) or other renewable farms connected to transmission grids. DER refers to small and medium wind, PV modules or other distribution generation resources connected to distribution grids.

Before allowing RES/DER integration to girds, network operators often do screening and network analysis to investigate if all technical aspects or requirements are met. Depending on sizes and connection voltages of RES/DER projects, load flow and dynamic studies are used often with a N-1 safety criterion. A short circuit is also used to check for any reinforcement of circuit breakers.

Though a RES/DER project is accepted for connection, there is no guarantee of curtailment or tripping under given circumstances in order to maintain a secure network operation. This curtailment part is covered in other KPI.

To measure the R&I contribution, KPI is calculated in percentage of additional RES/DER that can be connected to the grid above the BAU condition.

$$EHC_{\%} = \frac{HC_{R\&I} - HC_{BAU}}{HC_{BAU}} \times 100\%$$

Equation 1 Enhanced hosting capacity using R&I solutions

Where,

EHC %:enhanced hosting capacity of RES/DER when R&I solutions are applied with respect to BAU scenario.

HCR&I: additional hosting capacity of RES/DER when R&I solutions are applied with respect to currently connected generation (GW or MW)

HCBAU: additional hosting capacity of RES/DER in BAU scenario applied with respect to currently connected generation (GW or MW).

The formula is applicable for TSO with RES integration and for DSO with DER integration.

Example ex-post evaluation methodology

Although every project will identify a different measurement methodology, one possibility for calculating the hosting capacity is provided below (using field measurements).

Hereby is an elaboration of a possible method for DER hosting calculation used within GRID4EU [4], a relevant EEGI Labelled Project.

Step 1

Set the appropriate calculation conditions:

- Load condition: minimum load (identical to the baseline condition)
- Distributed Generation (DG) situation: DG enabled on the entire feeder (identical condition to the baseline condition)
- Medium Voltage (MV) busbar set-point: rated voltage (identical condition to the baseline calculation)
- Regulation algorithm: enabled. To simulate the algorithms, all generators must be set to 0.9 inductive power factor (this is a conventional value)

This would be completed using the Distribution Management System (DMS) as the calculation tool.

Step 2

Find the "highest voltage node" HVN

Step 3

Install a generator, in the HVN, with no generated active power and 0.9 inductive power factor.

Step 4

Increase the generator power until the voltage, in any node, reaches its maximum admissible value, or the current in any branch reaches its maximum admissible value. The corresponding power is the "Smart Grid hosting capacity HC_{SG}" (in kW)

Example ex-ante evaluation methodology

An example of a possible ex-ante evaluation methodology that could be used was developed by T&D Europe. The KPI evaluation methodology is based on the application of an Optimal Power Flow (OPF). This technique allows to quantify the KPI under investigation and, in the same time to identify the best asset of the intervention in order to assess its maximum impact on the issue under investigation. The OPF problem is composed of a set of constraints that represent the physical electric power flow equations and limits on electric variables. Nevertheless the presence of interventions that may drastically change the topology of the network (such as the application of FACTS devices) may introduce the necessity of revisit the classical load flow equation [5].

In principles a smarting action introduces at least one degree of freedom on which it is possible to act in order to maximize the effectiveness of the intervention on well defined issue (KPI). Since the OPF needs to measure the quantity that is directly related to the KPI, which represents the objective function of the procedure, the OPF is always capable of quantifying the KPI under investigation if the operational asset of the intervention is determined by the proposer.

In order to validate and acquire sensitivity with the defined KPIs, several simulations were performed on a benchmark transmission network (10-bus modified Cigré benchmark network, operated at the rated voltage of 225 kV) characterized by a relevant number of nodes and variety of players (TSOs, DSOs, renewable generations, conventional generations, large customers, etc.). The test case starting scenario is characterized by a total loss of 24.52 MW and a total load request of 1090 MW.

From the obtained results, it is possible to calculate the Power Saving KPI as detailed in Table 1, comparing the effects of possible smarting actions both in common base and incremental form.

	PS KPI – Common Base	PS KPI - Incremental
Active Combined FACTS	$\frac{24.52-23.39}{1090}\cdot 100 \cong 0,1\%$	$\frac{24.52-23.39}{24.52}\cdot 100 \cong 4,6\%$
Increase of Transmission Voltage	$\frac{24.52-8.00}{1090}\cdot 100 = 1.52\%$	$\frac{24.52-8.00}{24.52}\cdot 100 = 67.37\%$
RES Reactive Power Control	$\frac{24.52-23.89}{1090}\cdot 100 \cong 0.06\%$	$\frac{24.52-23.89}{24.52}\cdot 100 = 2.57\%$

Table 1 Power Saving KPI for FACTS application

The evaluation methodology can be applied in its present form to all "Specific KPIs" accounting for steady-state technical formulation. It can be easily extended other KPIs related for example to power quality, asset lime time and competitiveness of electricity market, provided that the proposed smarting actions are suitably re-modelled.

Active distribution system management could account for a set of multiple devices and systems, integrated to meet specific KPI targets. Profiting of on-line simulations, as well as of planning off-line studies, the distribution system manager could best address orders to optimize the distribution grid operation.

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CONCLUSIONS

The design and use of a set of KPIs in view of managing the EEGI Roadmap has been presented by the GRID+ project. While stressing the enabling role of electricity networks in view of achieving the European energy policy targets, (i.e. sustainability, competitiveness and security of supply), the developed framework introduces two categories of KPIs: implementation effectiveness KPI, which measures the completion of the EEGI R&I Roadmap; and expected impact KPIs, which are categorised as overarching, specific and project KPIs. The use of such KPIs will support the preparation for deployment of promising innovations demonstrated by the EEGI, in conjunction with national regulatory bodies. Deployment decisions will involve the measured KPI values obtained from the R&I activities (including large scale demonstration projects) that validate the deployment potential of the promising innovations. Scalability and replicability studies will be performed to aggregate results obtained from individual R&I projects (Project KPIs) to quantify the programme indicators (Specific KPIs) as described in this paper.

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