IGREENGrid Key Performance Indicators Definition

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Short Description (Max. 50 words):

This document provides an overview of the definition of each KPI selected for the evaluation of IGREENGrid smart grid solutions.

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Accessibility:

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1 Introduction and scope of the document

1.1 Objective

The objective of the document is to summarize the definitions of the KPIs selected by IGREENGrid team. These indicators are designed in order to evaluate homogenously the solutions tested in the different demonstrators located in the six European countries participating in the project.

1.2 Organisation of the document

The document is structured as follows:

- Section 2 details the definition of the Key Performance Indicators (KPIs) and the classification proposed for the IGREENGrid project.
- Section 3 details the definition of the first category indicators
- Section 4 details the definition of the second category indicators

1.3 Notations, abbreviations and acronyms

EEGI	European Electricity Grid Initiative
DER	Dispersed Energy Resources
DRES	Distributed Renewable Energy Sources
KPI	Key Performance Indicators
HC	Hosting Capacity
BAU	Business as Usual
R&I	Research and Innovation
SUT	Solution Under Test

Table 1 (Acronyms)

2 KPI definition/approach

Key Performance Indicators represent one of the evaluation tools proposed by the European Electricity Grid Initiative (EEGI). They quantify the success or the benefits of a Smart Grid solution tested on demonstrative networks.

KPIs can be defined for the evaluation of the solutions performance under numerous points of views. According to the necessities of IGREENGrid project and having considered the available information from the field tests, all the KPIs have been designed to consider the technical performance of the Smart Grid technologies.

The aim of this evaluation is to compare the different solutions tested in different places in a harmonized and normalized way. IGREENGrid team will attempt to use a common method of evaluation (applied to each network and solution) in order to select the most promising strategy for integration of Distributed Energy Resources (DRES). As mentioned above, the methodology is in line with the EEGI proposal and it is based on the comparison of two separate scenarios (Figure 1):

- The Research and Innovation Scenario (R&I) corresponding to a situation under test exploring a new solution.
- The Business as Usual Scenario (BAU) corresponding to a situation when the solution is not operative, as if it had never been installed.

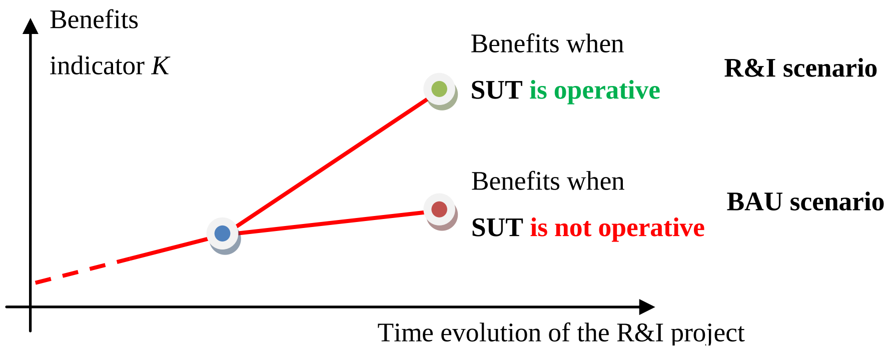

Figure 1 (Expected benefits of R&I activities with respect to BAU scenario)

In order to perform the proposed performance evaluation, IGREENGrid team has defined two categories of KPIs:

- **The first category indicators** evaluate technical aspects of the solutions related to the main expected benefits of the IGREENGrid solutions. These indicators evaluate the progress of the solution towards the primary objectives of the project: massive integration of DRES in the distribution network. The first category indicators evaluate the final impact of a solution once it is operating and installed in the network.

- **The second category indicators** evaluate technical aspects of the solution too, but they are related to the operation of the solution rather than on the final impacts it has on the network. To define the secondary category indicators, some objectives have been identified to describe the good operation of a solution. These objectives are called secondary objective because they are not related to the final aim of the project regarding the integration of DRES. The achievement of the secondary objectives is a requirement to reach the primary objectives, especially when real field tests are used as input data for calculation.

3 First category indicators

The first category indicators have been designed to evaluate the benefits of a solution according to the most important technical goals required for DRES integration in distribution networks. Each proposed KPI is related to a technical benefit (primary objective) that is expected to be reached by one or several groups of smart grid solutions as it is shown in Table 2.

Primary objective	First Category Indicator	Smart Solutions evaluated with this KPI
Improvement of the integration of DRES in the distribution network	Increase of DRES Hosting Capacity	- Voltage control - Storage plants installation - DRES generation forecasting - Demand response
Improvement of quality of supply	Quality of Supply improvement	- Voltage control - Storage plants installation
Improvement of the energy efficiency	Increase of network energy efficiency	- Voltage control - Storage plants installation - Demand response

Table 2 (First category of KPI)

3.1 DRES Hosting Capacity

According to IGREENGrid project's main goal, this first KPI appears as the most relevant for the evaluation of the solutions. The DRES Hosting Capacity quantifies the maximum admissible generation that can be injected in the distribution network avoiding any constraint violation. The evaluation of this HC is made by simulations using as inputs field measurements, a model of the physical network and of the Smart Grid solution equipment. The KPI is calculated by comparing the amount of HC in the BAU scenario (network operated as usual) and in the R&I scenario (network operated with the Smart Grid solution). Two different procedures have been selected for the evaluation of the HC benefits:

- **The time evolving DRES Hosting Capacity evaluation** that takes into account the different technologies of generation and weather data measures. It allows considering the time evolution of renewable-based generators and time critical Smart Grid solutions (i.e. storage).
- **The worst Case Hosting Capacity evaluation** that considers the worst case scenario in terms of constraints (i.e. all the generators producing at maximum capacity at the same, minimum consumption from loads, etc.).

3.2 Voltage Quality

The main challenge regarding the integration of DRES is to limit the impact of power injection on the quality of supply. The main aspect considered in IGREENGrid is concerning the effects of massive integration of DRES units on the voltage magnitude. According to this, the following aspects have been:

- **Voltage limit fulfilment**
  Field measurements are used to evaluate the voltage deviation with respect to the nominal voltage. The KPI evaluates the ability of the solution to keep the voltage as close as possible to the nominal value and, most important, the fulfillment of the adopted over/under voltage limits.

- **Voltage variability**
  The voltage variability gives an idea of the uniformity of the voltage magnitude from two different points of view:

  - **The voltage profile along the time** that evaluates the voltage fluctuations in a precise point of the network. It is quantified by the difference of the voltage value of two consecutive measurements on the same bus.
  - **The voltage profile along the feeder** that evaluates the voltage deviation between two consecutive nodes of network feeders. It evaluates the uniformity of load and generators allocation along the feeder.

  The KPI combines these two aspects and, from the comparison of the BAU and R&I scenarios, it evaluates the benefits provided by the Smart Grid solution.

- **Violation of the power quality limits**
  The indicator evaluating the violations of the power quality limits has been designed in order to consider:

  - **The duration of abnormal situations** that quantifies the total duration of this abnormal situations, such as interruption or voltage/current limit violations in the measurement points of the network.
  - **The amount of abnormal situations** that quantifies the total amount of abnormal situations, such as interruptions or voltage/current limits violations in correspondence of the measurement points of the network.

  The KPI combines these two aspects and, from the comparison of the BAU and R&I scenarios, it evaluates the benefits provided by the Smart Grid solution.

3.3 Network energy efficiency

The two previous KPI could help to evaluate the relevance of one smart grid solution to relief the network constraints. An additional relevant aspect, for the IGREENGrid objectives, is represented by the impact of the Smart Grid solution on the technical losses of the distribution network. The network efficiency is calculated thanks to the data collected from energy meters located in the demonstrators and comparing the global energy efficiency of the BAU and the R&I scenario.

4 Second category indicators

Second category indicators have been designed in order to evaluate the operation of the network in presence of the Smart Grids solution according to aspects that support the achievement of the first category objectives. Each second category indicator is linked to a specific objective and is relevant to evaluate a limited group of solutions depending on their impact (as reported in Table 3).

Secondary objective	Second category KPI	In which case the KPI is relevant
Optimization of the R&I solution usage time	Solution usage time	• Impact of the SUT on the network asset
Reverse/Reactive power flow reduction	Reverse flow indicator	• Reverse Power flow in primary/secondary substation • Reactive power exchange between the demonstrator and the upstream network
Forecasting accuracy increase	Effectiveness of the forecasting	• Forecasting errors of the DRES generation
Reduction of greenhouse gas emissions	CO_2 footprint	• Impact on the equivalent greenhouse gases emission

Table 3 (Second Category of IGREENGrid KPIs)

4.1 Solution usage time

This indicator focuses on the amount of time when the SUT is directly acting on the grid devices, loads or generators. It is calculated by measuring the number of action on a defined time window. This indicator can be used to evaluate different aspects of the SUT: for instance the impact on the maintenance planning, the amount of time in which the SUT is required, etc.

4.2 Reverse power flow indicator

Reverse power flow is a relevant aspect concerning the massive integration of DRES. In fact, current distribution networks are equipped with devices that are not normally designed to face the inverse of active power flow and large exchange of reactive power. This indicator evaluates the impact of the SUT on both the reverse and reactive power flow.

4.3 Effectiveness of the forecasting

Some IGREENGrid solutions use forecasting to predict the production of DRES and to plan network operation in advance. This means that, for these strategies, the forecasting accuracy plays a fundamental role as it has to be monitored in order to exhaustively evaluate the first category indicators related to forecasting-based solutions.

4.4 Greenhouse gas emissions

As any other project dealing with sustainable issues, the evaluation of greenhouse gases emissions is important. This KPI is based on the environmental impact of the SUT that is evaluated considering the following aspects:

- The resulting equivalent CO_2 impact has to be normalized in order to make the calculated performance comparable between the different projects. The (short and long term) CO_2 footprint is calculated for 1 kWh delivered to end consumers.
- The KPI is the result of the comparison of the carbon footprint calculated in the BAU scenario and in the R&I scenario taking into account the following contributions:
  - The energy supply from the upstream network: corresponding to the CO_2 emissions impact on the national energy mix.
  - The RES infrastructure: corresponding to the CO_2 emissions due to the installation, operation and dismantling of the infrastructure.
  - The network infrastructure: corresponding to the CO_2 emissions due to the installation, operation and dismantling of the electricity network. This last contribution is important for the BAU scenario since the scenario refers to grid reinforcement.

5 Conclusions

This document summarizes the first and second category indicators proposed for the IGREENGrid project and briefly explains the reasons of their use. It focuses also on the specific goals of each KPI, including the list of solutions for which their evaluation is expected to be relevant.

The KPIs assessment methodology is applied to IGREENGrid demonstrators in order to compare the performance of the tested Smart Grid solutions. This activity also allows the evaluation of the applicability of the designed KPIs on the considered networks and will enable to highlight the advantages/limitations of the proposed performance evaluation method.