A DATA REPOSITORY FOR AUTOMATED EVALUATION OF SMART GRID SOLUTIONS

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ABSTRACT

This paper describes the design of a data repository that is used to store scenarios from six successful smartgrids demonstration projects that are analyzed within the EC IGREENGrid project. The data repository is flexible and scalable and can be used to automatically calculate KPIs and facilitate the comparison between technical solutions.

INTRODUCTION

A variety of smart grid solutions has been introduced in order to facilitate the evolution and the progress towards the general scope: *"to allow European electricity networks continuously deliver an effective flexible capacity to integrate actions of grid users at affordable costs"*. The technical feasibility and the applicability of the solutions is assessed by the definition of Key Performance Indicators (KPIs) [1].

Within the EU R&DD project IGREENGrid1 the field experience in RES integration from six large scale demonstrators is collected and critically assessed in order to propose the most promising technologies and solutions also considering the different technical, climate, economic and regulatory solutions.

In order to perform this task in an effective way, a strategy is defined to share the knowledge gathered from the different demonstration projects. A set of standard data types have been identified, taking into account the data requirements for the calculation of KPIs, as well as the boundary conditions, which are mandatory for performing the qualitative analysis and comparison.

1 IGREENGrid (IntegratinG Renewables in the EuropEaN Electricity Grid) is a collaborative project co-founded by the European Commission under the 7th Framework Programme, with grant agreement n° 308864, in the Energy area.

The identification of relations between data has led to the design of a data repository to automatically calculate the KPIs and facilitate the comparison between technical solutions. The system is based on a multi-tiered architecture to increase flexibility, scalability and enhance the system's ability to adapt for future requirement updates. The main characteristics of the data repository are:

- A flexible mechanism to store data from different sources/systems. The data sources may be exports from DMS, Databases or other software platforms in different format types such as Excel, text, CSV or XML.
- The data may contain both static data (e..g. network description, DG technical characteristics etc) or measurements/calculations (e.g. voltages on feeders, production of DGs etc)
- Automated KPI calculations according to standard formulas
- Extensible framework for facilitating data needs for future KPIs and further standardized calculations. This has been achieved by designing a database that will easily integrate other type of measurements or new characteristics in the DGs.
- User friendly environment with extra supporting functionalities such as view/search data or save accompanying files. The environment is Web Based and the user depending on the access rights may read the KPI (simple user) or add/manage data (advanced user)

KEY PERFORMANCE INDICATORS (KPIs)

The European Electricity Grid Initiative (EEGI) has proposed a framework for the assessment of the achievement towards the European energy policy targets.

The developed framework introduces a set of Key Performance Indicators (KPIs), each one having a specific management goal in the Research and Innovation Roadmap of EEGI. The KPIs are used to evaluate the network differential performance between two situations: the Smart grid scenario and the Business As Usual (BAU) scenario.

The main focus of the IGREENGrid project is the integration of DRES in distribution grids. This has led to three main KPIs for the evaluation of the demonstrated technologies:

- increase of hosting capacity;
- improvement of the quality of supply;
- energy efficiency improvement.

Apart from the main KPIs, a secondary subset of KPIs has been defined, as follows:

- optimization of the R&I solution usage time,
- reverse/reactive power flow reduction,
- forecasting accuracy increase and
- reduction of greenhouse gas emissions.

The calculation of the KPIs includes standard step-by-step procedures which are implemented in the dataset of the IGREENGrid demonstration projects and are described in [?]. The KPIs can rely on simulations based on real measured inputs, considering cases in which the grid is facing extreme situations and Smartgrid solutions can be used to improve its performance. KPIs can also be used to compare the performance of a Smartgrid application in different networks or to compare the performance of different approaches in a specific grid configuration.

STRUCTURE OF THE DATA REPOSITORY

System Architecture

The data repository was designed to handle a very large and diverse set of data (grid topology, measurements, results etc) that needs to be stored and manipulated for use in a multitude of operations and calculations. To address the need for a flexible system that will allow easy integration of future modifications, a modular approach was used. The system comprises three main modules: Data Handling, Offline Data Processing and User Interface Module as depicted in Figure 1.

Data Handling Module

The backbone of the repository system is the Data Handling module. It is responsible for the raw data storage and retrieval operations. To cope with the amount of data an SQL Server 2008 RDBMS was used as its central data storage system. The database was designed to

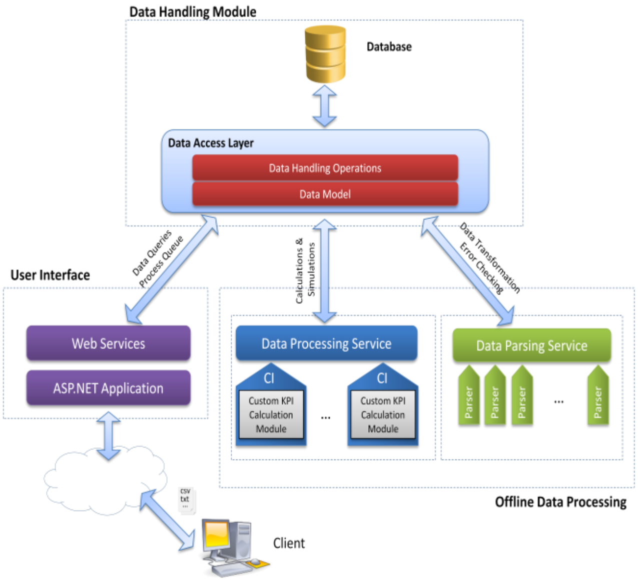

Figure1. Repository architecture.

support a wide range of objects and measurements in order to adapt to new user needs. In addition to the basic services, the database module provides an intermediate Data Access Layer (DAL) as an interface to the other repository modules. The DAL exposes an object model and set of methods that are used for communication with the database that enhances the system's flexibility and ease of new module integration.

Offline Data Processing Module

The Offline Data Processing Module handles reading, transforming and performing calculations on the incoming data. The user requests for data parsing and processing are not immediately carried out (online). Instead, they are added in a process request queue (offline) to optimize performance and limit server resource usage. The module consists of two independent services running on the same application server, Data Parsing and Data Processing.

Data Parsing Service

The Data Parsing Service is responsible for retrieving the data in the uploaded user files. In order to eliminate the effort needed for transforming the data on the client side, the Data Repository provides the user with the option to create a template of the data files based on their own export system or use an already existing template. The template is then used to implement a custom parser that will interpret and transform the data contained in the user files. The Data Parsing Service provides a Common Interface (CI) used by the parsers in order to interact with the service enabling easy integration of new user templates. Currently supported formats include (but not limited to) text, comma separated values, mat power and Excel files.

Data Processing Service
The Data Processing Service handles the retrieval and transformation of the data needed for the calculation modules, reading and storing their results in the repository. To provide support for third-party calculation modules implemented using various tools (stand-alone exe, matlab etc.) the Data Processing Service provides a calculation module wrapper that interacts with it in a predefined fashion. This approach facilitates the integration of new custom calculation modules enhancing the scalability and maintainability of the repository.

User Interface

A web based interface was developed using Microsoft ASP.NET MVC pattern and Web API Services along with client side scripting technologies (JQuery, ajax). It aims in providing a user friendly interaction with the Repository System, exchange and query the data stored in it. Only an overview of the system functionalities is presented in this paper.

Data Input
Demo location users upload a file template (a short description of their file structure and data contained in it). Based on their template a parser is implemented using the parsers common interface mentioned previously. When the parser becomes available, users can import their data by uploading the related files. Templates and data files uploaded can include either grid static characteristics (topology, technical characteristics, parameters etc) or raw measurements and calculated KPI results. A set of files containing grid characteristics and raw measurements defines a scenario that is bound to a Demo Location.

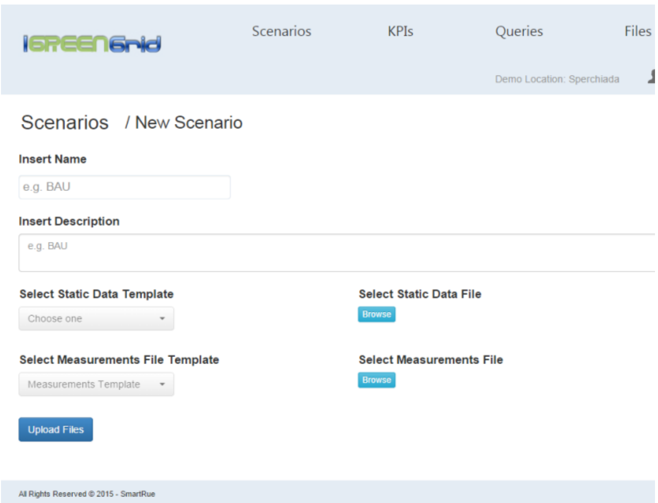

Figure2. Display of Scenario screen.

General information documents
In addition to the data related to the KPI calculations, the Repository allows the user to provide further information on their system such as boundary conditions of the calculations for qualitative comparisons. Examples of information that can be included are regulatory aspects, market conditions, technical details of implemented functionalities/control strategies. Each of these informative data is associated with a Demo location. The Repository offers the users the ability to better describe the contents of their data by using a set of predefined or user defined tags.

KPI Calculations
Although the repository is designed to automate the KPI calculation process, users can upload their own results. The automatic KPI calculation uses the data uploaded and calculates the KPI obtained by comparing the performance of a base case (BAU) with a smartgrids solution. For complex and time consuming KPI calculations the system queues the request and notifies the user later about the results of the calculations.

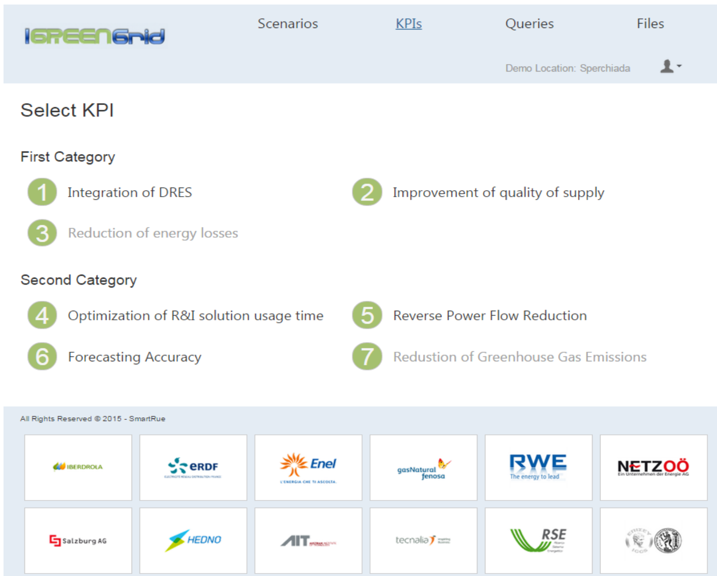

Figure3. Display of the KPI menu

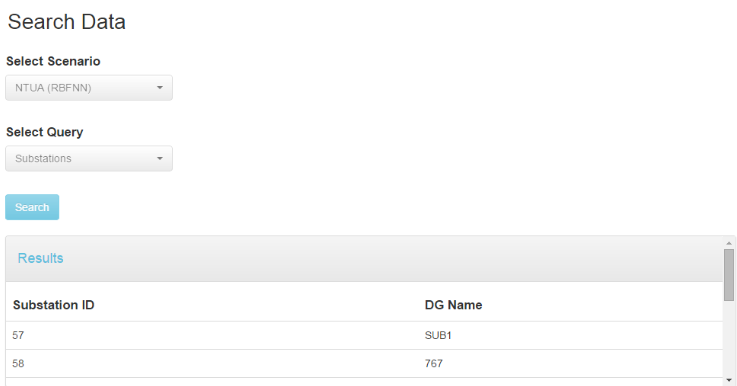

Figure3. Display of Data Queries screen

Data Queries

Data stored in the Repository can be queried by the users using a predefined set of criteria. The criteria and the most common queries were adopted after consulting with the demo partners

Additionally the Repository allows the user to search the uploaded files based on a set of tags that are used to describe them.

SAMPLE RESULTS

The IGREENGrid Demo projects

The IGREENGrid project deals with six demonstration projects, which are implemented by the corresponding Distribution System Operators (DSOs) to show the integration of new technologies into distribution grids with the aim to increase the Distributed RES hosting capacity. The main target of the project is the comparison of the results of these demonstration projects and the identification of the most promising solutions for the reliable and efficient integration of Distributed RES.

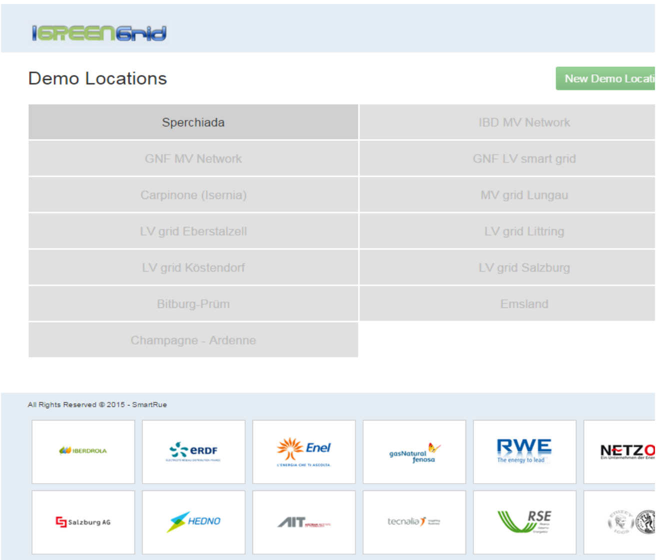

Figure 4. The 6 Demo Projects of IGRRENGrid

In the following, indicative results from the Greek demo site are presented.

Sperchiada Demo Case

The Greek pilot project is based on a HV/MV substation at Sperchiada where a relatively high industrial consumption was foreseen, but activity has been progressively reduced, while the installation of PV systems together with small hydro systems has steadily grown. As a result, high Distributed RES penetration, causing reverse power flows, is currently observed.

The core of the demo project is to use the data available from two different systems, the DMS (Distribution Management System) and the AMR (Automatic Meter Reading) connected to the telemetry centre of Hellenic Distribution Network Operator (HEDNO). The Greek Demo project exploits data collected from electronic meters installed at MV customers and RES (PVs) connected to two MV feeders located at Sperchiada. The MV lines are fed by HV/MV substations and they are feeding MV/LV substations, MV loads (mainly industrial/commercial customers) and RES installations.

The outcome of the demo project is a set of distribution management tools, which are based on the AMR infrastructure for data acquisition of MV Networks and deploy several advanced functions extending the main functions of stochastic RES (PV) forecasting and probabilistic load flow. More specifically, advanced functions are implemented, such as improved monitoring of the system state, identification in advance and management of congestion and operational limits violations (e.g. overvoltages), RES Hosting Capacity Evaluation Studies, Assessment of the impact of P-V control policies for DER and related production set-points. This is the first attempt to utilize the AMR data for the support of the power system operation and planning. One of the main objectives of the demo project is to enhance the grid operators' visibility of abnormal situations in the grid, caused mainly by the high RES penetration. Figure 5 shows the scenarios used in the Sperchiada studies that include several operating periods and the simulation of several smartgrid solutions. In the following the calculation of 2 indicative KPIs, namely the increase of DER Hosting Capacity and the Forecasting Accuracy are presented.

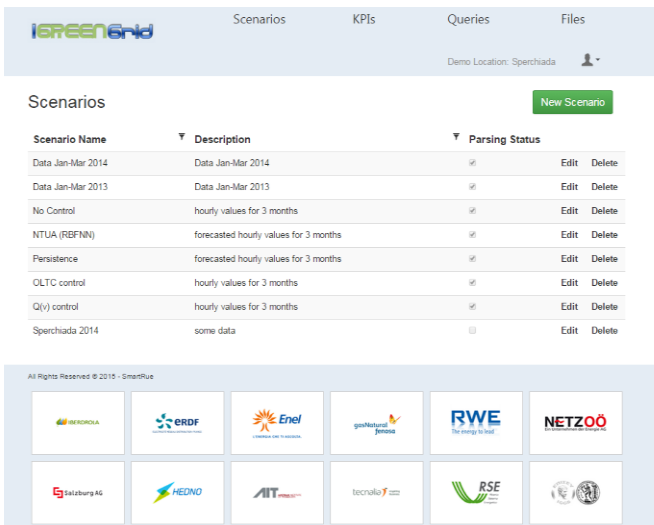

Figure 5. The scenarios considered for Sperchiada

Calculation of the DER Hosting Capacity KPI

The DER Hosting Capacity is estimated using a single bus approach. More specifically, this method estimates, for the most electrical distant bus of the network the maximum amount of active power generation that can be injected while satisfying operating constraints, such as the thermal limits and the maximum voltage deviation. It assumes that the whole installed DER capacity and load is concentrated at this specific node. Three different cases have been included in the scenarios.

1. No control

In this case the algorithm provides the DER Hosting Capacity (HC) assuming absence of DER or network control. It is assumed that the produced power at the most remote node s increased until the voltage exceeds the maximum admissible value, +5% of its nominal value. It is assumed that the DG operates at cosφ=1. The DER HC is calculated equal to 1.66 MW

2. The OLTC Control

Under the same assumptions, the On-Load-Tap-Changer (OLTC) adjusts the feeder's voltage in order to maintain the bus voltages in the distribution network within acceptable limits. The DER HC is increased to 2.21 MW.

3. The Q(U) Control Case

DER control to operate at lagging power factor is assumed, absorbing reactive power from the grid. The absorption of reactive power can partially compensate the voltage rise at the buses where DER are connected. Thus, the effect of DER reactive power control on DER hosting capacity is examined. It is assumed that the power factor of DER operation cannot be lower than 0.9 and that the reactive power exchange between node's DER unit and the grid is expressed by a fixed *Q*(*V*) control curve. The DER HC is increased to 2.81 MW.

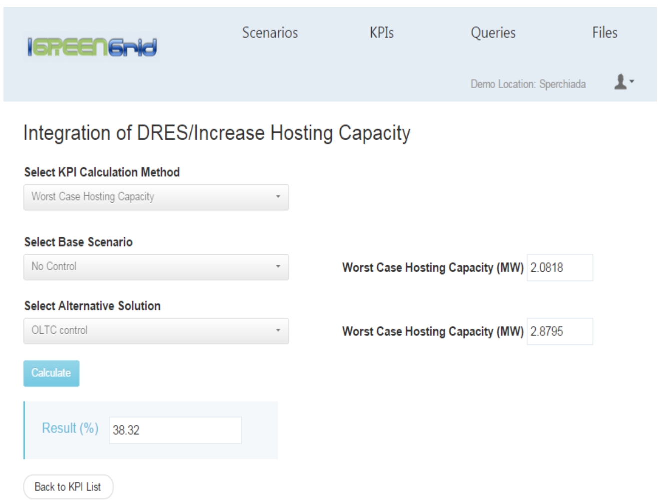

Figure 6. Calculation of Hosting Capacity KPI

Figure 6 shows the increase of the RES Hosting Capacity obtained within the Data Repository when the no-control case is compared with the OLTC control scenario. An increase of 38.32% is calculated.

Calculation of Forecasting Accuracy

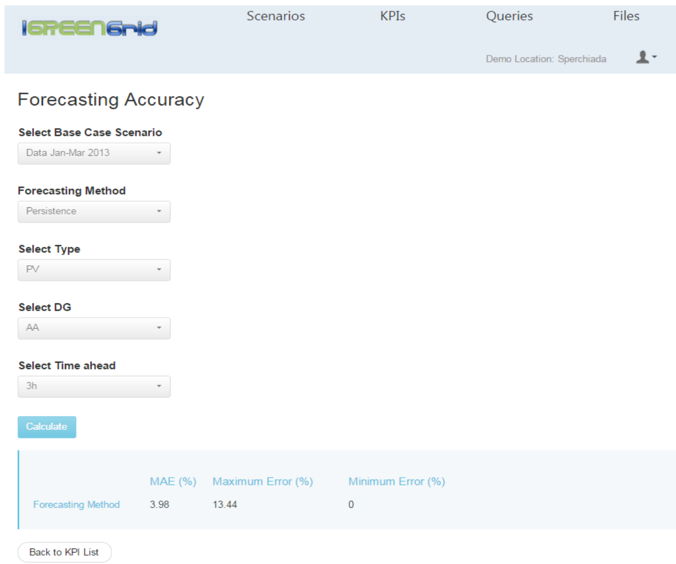

Figure 7. Calculation of Forecasting Accuracy

Figure 7 shows an example of the calculation of the forecasting accuracy of one of the applied forecasting methods (Persistence) to a time-series of power measurements at a selected PV location for 3 hours ahead.

CONCLUSIONS

The paper describes the basic features and application examples of a Data Repository that has been developed within the IGREENGrid EU project. The Data Repository is used to automatically calculate KPIs and to facilitate the comparison between technical solutions. The system is flexible, scalable and can be adapted for future requirement updates, so it can be used for the automatic comparative assessment of future smartgrids solutions and demo cases.

Acknowledgments

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[1] Marco Rossi, et al. "On the Definition and Applicability of Key Performance Indicators for Evaluating the Performance of Smart Grid Concepts", paper 1281, *23rd CIRED conference*, Lyon, 15-18 June 2015.