SMART GRID TECHNOLOGIES EVALUATION THROUGH KPIS

Mariano GAUDO
Unión Fenosa Distribución– Spain
mgaudo@gasnatural.com

Roberto GONZÁLEZ SAINZ-MAZA
Iberdrola, S.A. – Spain
rgonzalezsm@iberdrola.es

Samuel BORROY
CIRCE[1] – Spain
sborroy@fcirce.es

Laura GIMÉNEZ DE URTASUN
CIRCE[1] – Spain
lauragdu@fcirce.es

Susana MARTÍN ARROYO
CIRCE[1] – Spain
smartin@fcirce.es

Miguel GARCÍA-GRACIA
CIRCE[1] – Spain
mggracia@fcirce.es

[1] Research Centre for Energy Resources and Consumption

ABSTRACT

New Smart Grid (SG) technologies tested in the demonstration sites that are appearing all along DSO's may not provide all the information that would be necessary in order to take the decision of deployment for that technology to the general grid. This paper addresses the methodology followed in order to evaluate this general deployment using power system simulations and the estimation of Key Performance Indicators (KPIs). This work is being developed in the framework of PRICE-RED and DISCERN projects.
(Smart Grid, KPIs, power system simulations)

INTRODUCTION

Distribution System Operators, (DSOs), actual challenge is to adapt their grid operations and business to newly developed solutions for medium and low voltage grids. On the other side, changes and new technologies are not easily implemented in the electric companies due to the high payback period that every new deployment will have. Hence SG demonstrators are growing in every country, as every DSO wants to try its proposals and the different manufacturers' solutions in advance to a wider deployment.

The critical point comes when the decision to extend the use of all, or a couple of the solutions implemented in the demonstrators has to be taken. The technologies may have been tested, but the effect of a massive deployment of all or a couple of these solutions is still not clear. This is because the evaluation in demonstration sites is done locally, with limited capacity or tools to estimate the impact that those solutions could have in other grids.

The tool addressed in this paper is the technical evaluation and replicability and scalability assessment of SG technologies solutions through the proposal of KPIs and the objective function.

In order to evaluate the performance of a SG, the first step is to define the objectives of the DSO's that could justify the installation of these new technologies, not only in a demonstration site scenario, but as a standardized solution. One of the most important goals considered for the DSO is the cost-saving optimization. This objective considers all the remunerations and costs involved in the normal operation of the company, optimizing consequently the level of intelligence required for the grid.

After defining the objectives, it is important to establish how they will be evaluated, and this will be done through the proposal of the KPIs. As an example, the most relevant KPIs could be the demand curve flattening, amount of distributed generation, average system interruption duration index (ASIDI), number of installed devices and the investment required among others.

When evaluating a new SG project with different dimensions to those tested demonstration sites, some of the KPIs that will be needed could be simply upgraded from what was tested, although most of them will need to be estimated. This estimation of the KPIs has been achieved by simulation, considering the same demonstration site grids. In the paper, the developed method to calculate KPIs for any grid will be shown. This method to evaluate these KPIs should be validated with the results measured in field and allows to estimate the technical replicability and scalability of the different technologies used.

In this way it would be possible to compare different solutions and networks, and it is critical to define easily assessable and useful indicators that could evaluate the objectives.

This work is being developed in the framework of PRICE-RED and DISCERN projects, [1]-[2], where different European DSOs, and manufacturers are involved in order to share the results they have obtained in their demonstration sites and to determine the replicability of the technological options.

This paper is structured so that in the following section the selection of possible objectives is introduced. At section: "Evaluation of objectives", the evaluation through KPIs is explained. At section: "Methodology" it is explained how the upgrading of the KPIs is done. And at the last section are explained the conclusions on how this methodology helps for the replicability and scalability of SG solutions.

OBJECTIVES SELECTION

As a general rule, the objective that any SG should have is related to an improvement of the efficiency without jeopardising the reliability and quality of the power supported to customers. This is usually done through an

increase of the monitoring and control of the grid and in many cases through the integration of renewable energies.
On the other hand are the authorities objectives, like for example the European commitments for 2020, [3], which are: reduction of consumption of primary energy, increase of the amount of renewable energies and reduction of the CO_2 emissions.
The main aim for a DSO may not be following European commitments. Instead, they could have other goals, like reduction in faults restoring time, improvement of served power quality, reduction of maintenance, losses or billing costs. Nevertheless, DSO's objectives are not necessarily apart from those of the authorities as it may seem. They could be compatible if expressed and oriented in the correct way.
As it was said before, the overall objective should be efficiency and in this pathway, all the previously mentioned objectives, could be expressed together as a part of a cost-benefit analysis, [4].
Any new development should be evaluated through its initial investment and its annual costs and savings. Therefore, even authorities commitments can be expressed in economic terms, and be added into a general efficiency objective, in which all the particular objectives should be expressed.
This is why each DSO objectives should be really clear, in order to allow their expression in an economical way.
Another benefit from this standpoint is that in the case that any authorities commitments could be seen as not beneficial from an economic point of view, the measurements to be taken could be settled and evaluated in a quite accurate way.

EVALUATION OF OBJECTIVES

The way to evaluate the objective that each DSO has set, and to do it in an independent way is by establishing standardized measurements which could enable the comparison in between two different stages of deployment in one grid, or in between two different grids. And this is exactly what KPIs do.
KPIs provide specific information on the state or condition of the grid and, as it is defined by EEGI, [5], KPIs are designed to monitor the evolution of certain deployments within an innovation project.
Each objective is assessed according to the increment of the KPIs involved in its evaluation, which means that an initial/reference value has to be considered, as the starting point of the evaluation of the objective. The increment of the objective would be evaluated as follows in equation (1):

$$\Delta(I_x) = \left(\frac{I_x - I_{x\_0}}{I_{x\_0}}\right) \qquad (1)$$

Where: I_x is the actual measurement of the KPI and I_{x_0} is its initial measurement.

The way in which each KPI is influencing the achievement of the objective is related to the weighting factor, P_{Iy}, set for it. In the next equation (2) it can be seen a general objective function:

$$O_x = P_{I_y}\Delta(I_y) + P_{I_z}\Delta(I_z) + \ldots \qquad (2)$$

The establishment of weighting factors corresponds to each DSO, as it is a strategic decision of each company.

METHODOLOGY

As explained at the introduction, this paper is based on the work done at PRICE-RED and DISCERN projects, where different DSOs with different SG implementations in their own demonstration sites have gathered together, in order to share their experiences and to reach conclusions on the replicability and scalability of each of the presented solutions.
Before explaining the simulation methodology, some essential concepts related to previous tasks of the DISCERN project must be explained.
The "3L" concept main idea is summarized in Figure 1.

Figure 1 3L role concept

At the 3L concept, each DSO takes on one of the three available roles: leader, learner or listener, in relation to a specific functionality to implement in a SG. Firstly, leading DSO projects are characterized by the fact that the respective DSO has already developed and implemented a solution for the specific SG functionality. Secondly, learning DSOs are interested in the implementation of the technical solution for a functionality. In the third place, listening DSOs will follow functionalities on which they have not yet made any considerations regarding the concrete implementation but are keen to take into considerations the results from the evaluation.
Once the 3L concept is cleared up, the simulation methodology will be explained.
Simulations will enable the calculation of a considerable amount of KPIs, and the comparison of them with the set of KPIs obtained in field at DSOs demonstration sites.
The main difference between the deployment of a functionality at a demonstration site and its simulation is that through simulations we are able to deploy many different levels of technology, and to control some

features of the grid state, like the generation, demand, faults, equipment or communication failures, … Taking advantage of simulations flexibility allows to select the specific grid conditions for which we want to test and evaluate each functionality.

For each functionality, the next procedure will be followed: First, verification and validation of the simulation model; secondly, simulation of scenarios and third, simulation at benchmark network.

Verification and validation of the simulation model.

Simulation models are approximate reproductions of real-world systems, but they never exactly emulate the real-world system. Due to that, simulation models must be verified and validated according to the real data measured in the real-world. For this reason, the first phase of the simulation methodology includes the validation of the simulation model with the Leader DSO.

As it was explained, leader DSO has already implemented and applied the functionality, which means that it can take measurements from the demonstration site, and can provide the KPIs that are affected by that functionality. The conditions for which those KPIs were measured should be reproduced at the simulation, with the same architecture, generation and load, and SG functionality technology deployment level. The comparison of the KPIs measurements at both, demonstration site and simulations, should give the degree of accuracy obtained at simulations, and validate the functionality model for its implementation in other DSOs grids.

In order to perform correctly this validation, the network data of the Leader DSO in each functionality needs to be modelled.

Simulation of scenarios

Once the created simulation model is validated in the previous stage, all the simulation scenarios defined for each functionality will be carried out at learner DSO network.

Each simulation scenario defines the set of variable features that will be established for the simulation in order to obtain the behaviour of the grid with those specific features.

In order to set an example, the simulations scenarios will be shown for one of the functionalities from the EU commission framework [6], the functionality B5b: “Impact of Automatic Grid Recovery System for the MV grid management”.

For the selected functionality B5b, the simulation task would develop studies to determine the optimal number and location of sensors in order to obtain the maximum benefit from the fault identification and optimal grid reconfiguration tools.

The different strategies for optimal operation and control would be as well studied with the simulation tools, offering a wide range of scenarios to test the algorithms or strategies.

Simulation scenarios would have been set for different technology and automation levels, for different Distributed Energy Resources, (DER), levels and for different conditions on the grid.

The scenarios that would have been simulated are shown in Table 1. At each scenario there would have been tested the normal operation conditions, faults on grid sections and the possible reconfigurations.

Table 1 B5b simulation scenarios

		Scenarios											
		1	2	3	4	5	6	7	8	9	10	11	12
Technology and automation level	Actual	x	x	x									
	Devices deployment (10%)				x	x	x						
	Devices deployment (20%)							x	x	x			
	Devices deployment (50%)										x	x	x
DER integration level	0%	x				x				x			
	20%		x				x				x		
	50%			x				x				x	
Conditions of the grid	Normal operating conditions	x	x	x	x	x	x	x	x	x	x	x	x
	Faults in grid sections	x	x	x	x	x	x	x	x	x	x	x	x
	Reconfiguration	x	x	x	x	x	x	x	x	x	x	x	x

As it can be seen, simulation advantages in this case are: to deploy four different levels of technology and to control some features of the grid state, like the DER level, or the operation conditions: normal, with faults, or with a reconfiguration of the grid.

For each functionality, specific as well as common KPIs have been selected in order to allow a standardized evaluation for all the grids. In the simulations referring to functionality B5b the specific KPIs that would have been measured could have been: DER hosting capacity, ASIDI improvement, number of switching operations after each fault/outage event, number of sensors/data to achieve the functionality and energy losses, for example.

This approach provides a valuable wide range of results to learner DSOs because these learners will have not only the real results available at leader DSOs but also the simulated results generated from the model of their networks. Therefore, this second stage of the simulation methodology deals with the question of replicability of the solutions initially formulated in DISCERN.

Simulation at benchmark network

In a similar way as it was defined at the second phase, once the created simulation model is validated at leader network, all the simulation scenarios defined for each functionality will be carried out at a benchmark distribution network.

A benchmark distribution network was selected for each, MV and LV functionalities.

These benchmark networks were obtained from the

International Council on Large Electric Systems, CIGRE, [7]-[9]. Some assumptions and small changes were made in order to adapt these networks to the project interests, but they remain being general distribution grids. Both networks can be seen at the next Figure 2 and Figure 3.

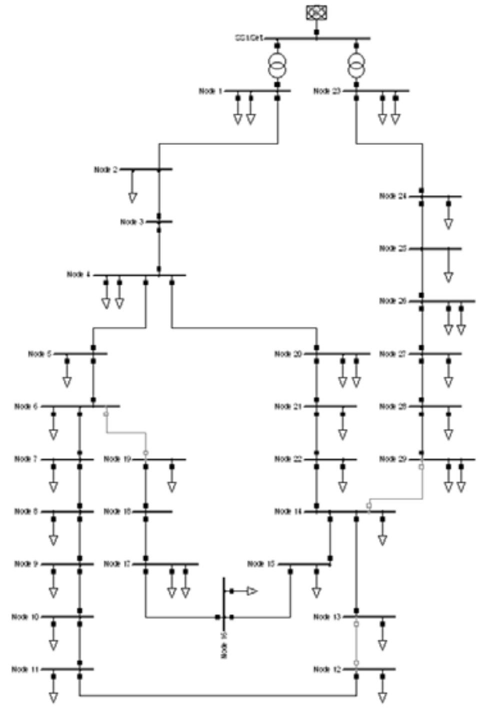

Figure 2 One-line diagram of the MV benchmark distribution network

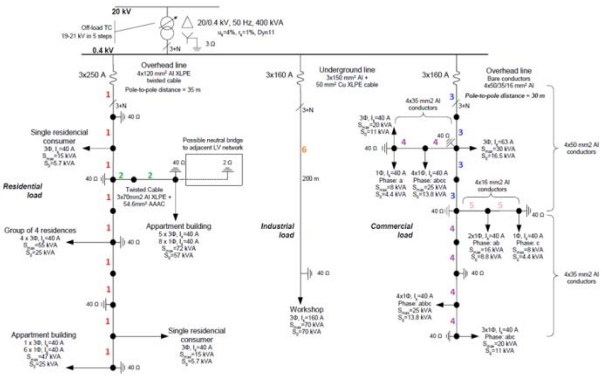

Figure 3 One-line diagram of the LV benchmark distribution network

To follow with the example stated before, one scenario example for functionality B5b, can be seen in Figure 4 implemented at the MV benchmark network.

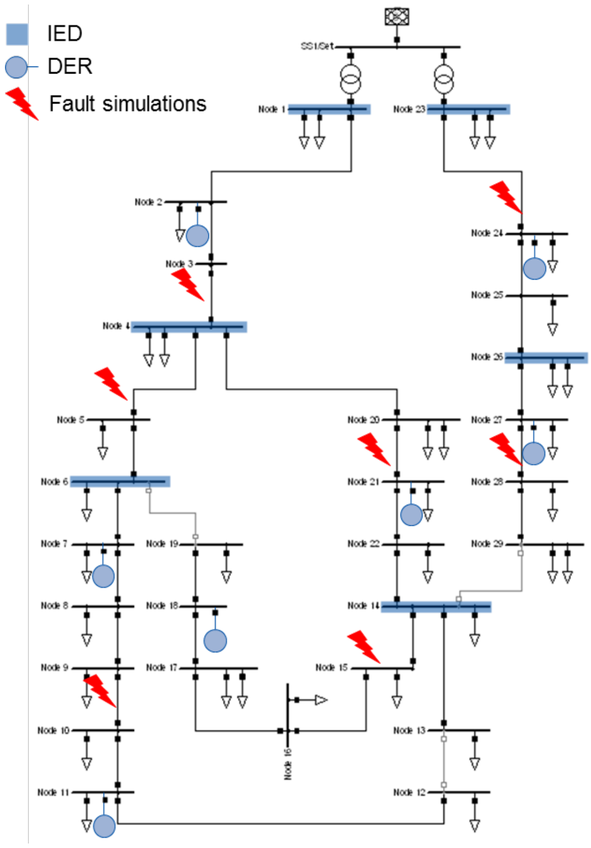

Figure 4 Scenario Example for functionality B5b at MV benchmark network

This scenario example corresponds to an automation level of 20% of the secondary substations, a DER integration level of 20% and distributed faults along all the possible grid sections. At this scenario, there would be tested as well the normal operating conditions, and the reconfiguration possibilities that the automated secondary substations could allow.

By using these benchmark networks it is assessed once again the replicability of the solutions, as it was done with the learner DSO. Besides, with these networks it is easier to assess the scalability of the solutions, as these grids can be simply enlarged by multiplying the number of its independent units. A schema of this possibility is shown in Figure 5.

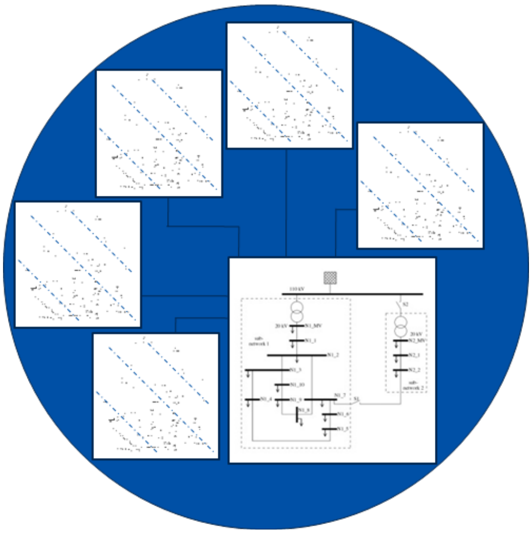

Figure 5 Schema of enlargement of a benchmark grid

Furthermore, an interesting issue is the way in which the simulation methodology deals with confidentiality concerns. Actually, confidentiality is one of the obstacles that may arise from collaborative projects due to the common difficulty for sharing information between DSOs or to publish the results of the project. Results on the benchmark network simulations are as valid as those from DSO grids, and have no confidential problems.

CONCLUSIONS

At this paper it has been shown the developed method for the evaluation of SG solutions through KPIs with the aim to assess which of those tested solutions may be deployed to the general distribution grids.

The combination of demonstration site tests with simulations enables a whole bunch of results, for which we have the certainty of having a validation of its accuracy, at the same time that the number of experimental test and hence the costs for such an amount of results have been cut.

The results that each DSO will obtain for its final evaluation depend on the objectives that they have initially set, as this method only provides the KPIs evaluation, which is an independent measurement. Therefore a big stress has to be done in a correct selection of the objectives and in the way that these objectives are calculated through the given KPIs.

ACKNOWLEDGMENTS

The authors would like to express their appreciation to Iberdrola Distribución, Unión Fenosa Distribución and RWE for contributing with valuable comments under the PRICE-RED and DISCERN projects framework.

This work has been partially supported by the Spanish Ministry of Economy and Competitiveness under the PRICE-RED project (IPT-2011-1504-920000).

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007–2013) under grant agreement No. 308913.

REFERENCES

[1] PRICE-RED project, http://www.priceproject.es/

[2] DISCERN project, http://www.discern.eu/

[3] EU Commission, 2011, “Europe 2020 strategy”, http://ec.europa.eu/europe2020/index_es.htm

[4] ENTSO-E, 2012, “Guideline for cost-benefit analysis of grid development projects”.

[5] EEGI, 2013, “EEGI Research and Innovation Roadmap 2013-2022”.

[6] EU Commission Task Force Expert Group, “Functionalities of smart grids and smart meters: EU Commission Task Force for Smart Grids Expert Group 1”, 2010.

[7] Rudion, K.; Orths, A.; Styczynski, Z. A.; Strunz, K.; "Design of Benchmark of Medium Voltage Distribution Network for Investigation of DG Integration", Power Engineering Society General Meeting, 2006. IEEE, pp. 6.

[8] Styczynski, Z. A.; Orths, A.; Rudion, K.; Lebioda, A.; Ruhle, O., "Benchmark for an Electric Distribution System with Dispersed Energy Resources", Transmission and Distribution Conference and Exhibition, 2005/2006 IEEE PES, pp.314 - 320.

[9] Papathanassiou, S.; Hatziargyriou, N.; Strunz, K., “A benchmark low voltage microgrid network”, Power Systems with dispersed generation: technologies, impacts on development, operation and performances, CIGRE Symposium, April 2005, Athens, Greece.