INTEGRATED SMART GRID CROSS-FUNCTIONAL SOLUTIONS FOR OPTIMIZED SYNERGETIC ENERGY DISTRIBUTION, UTILIZATION STORAGE TECHNOLOGIES

www.inteGRIDy.eu

A KPI-Based Evaluation for InteGRIDy Project Framework and tools performance

Chris Ogwumike, Tariq Ahmed, Huda Dawood, Bjarnhedinn Gudlaugsson

Teesside University

ARTICLE INFORMATION	ABSTRACT
Published day month year Key words: Key Performance Indicator, Evaluation methodology, Baseline assessment, Smart grid.	The overall impacts and success of the different tools implemented within the inteGRIDy project were assessed through the analysis of Key Performance Indicators (KPIs) that appropriately reflect the technical, economic, environmental, and social domains of the respective inteGRIDy thematic pillars. Teesside University led the evaluation of the overall inteGRIDy framework and tools performance, considering the evaluation of improvements brought by individual components of inteGRIDy-enabled smart solution implementations and user experience across the ten pilot sites. The analysis and interpretation of findings for the pilot use case evaluation, future development, and potential exploitation of the partner tool were ascertained. Overall, the smart solution implementation across the ten pilot sites resulted to achieving the inteGRIDy set objectives with regards to energy consumption reduction & cost optimization (Isle of Wight, Terni, Barcelona, and Xanthi); DR flexibility / stability (Isle of Wight, San Severino, St Jean, Nicosia, Barcelona, Lisbon, and Thessaloniki) and carbon dioxide emission reduction

	(Isle of Wight, Lisbon, Ploiesti, and Thessaloniki).

Introduction

The overall impacts and success of the different inteGRIDy framework and tools implemented within the respective pilot sites was led by Teesside university in collaboration with partners from the pilot sites. The evaluation of pilot use cases was assessed through the analysis of KPIs reflecting the technical, economic, environmental, and social domains of the respective inteGRIDy thematic pillars, following the methodology and best practices proposed in D1.4 [1].

This white paper takes into consideration the related inteGRIDy project work packages since the information they provide defines the inteGRIDy KPIs, metrics, framework, and methodology, resulting to the overall improvement of inteGRIDy-enabled solutions and grid performance.

The analysis, interpretation of findings and a conclusive remark on the pilot use cases is provided, upon the completion of individual pilot use case evaluation.

Data collection

Data collection methods (both qualitative and quantitative) have been established and used for baseline assessment and smart solution scenarios. Data used in the KPI evaluation was obtained from different sources such as data from Building Management System (BMS) and Building Automation System (BAS), conventional and smart meters, utility bills, battery management systems and Electric Vehicle (EV) charging platforms, smart sensors, online web services and questionnaires.

Evaluation Methodology

The first list of KPIs was reported in D1.4 at the beginning of the project and later updated in D8.1 [2]. During the evaluation, it became imperative to review and validate the KPIs with respect to the pilots' needs, considering the changing effects (amendments) on some pilot sites. In some cases, new set of KPIs that show significance to the use case objectives were selected for evaluation as local KPIs (specific to the pilot site). The validation of KPI evaluation parameters and the objectives of the pilot site use-cases naturally evolve after closer interaction with the pilot partners.

For the KPI evaluation, the baseline scenario was compared against the smart solution implementation in the pilot sites. KPIs related to Demand flexibility were evaluated considering the requested and potential energy demand flexibility (increase or decrease in certain percentage of energy demand) based on the contractual framework applicable to the pilot sites.

Outcome

The KPI evaluation results are presented for the respective performance domains (Technical, Economic, Environmental and Social) across pilots. KPI results for the Isle of Wight pilot M7 Energy storage use case are presented in Table 1 to 3 below. For Technical KPI evaluation, Energy consumption, peak to average ratio, Energy consumption reduction, demand flexibility ratio and peak load reduction are presented in Table 1. For the economic KPIs, percentage difference of 68% was obtained in the retailer cost of energy between the baseline and smart solution costs. Whereas there is a significant reduction of 982.87kg CO_2 emission due to smart implementation as shown in Table 3.

For some pilot sites, the results and analysis of the energy consumption reduction (as shown in Figure 1) are presented to show the visual difference between the baseline energy consumption and the consumption after smart solution implementation.

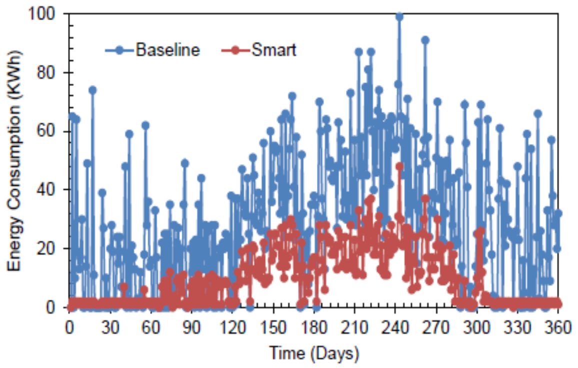

Figure 1. Minus7 Energy Storage System Energy Consumption

Table 1. Technical KPI Results for Isle of Wight M7 Energy storage use case

KPI Data	Unit	Baseline	Smart
Energy Consumption	kWh	691	48
Peak to Average Ratio	%	296	129
Energy Consumption Reduction	kWh	643	
Demand Flexibility Ratio		0.930535456	
Peak Load Reduction	%	64	

Table 2. Economic KPI Results for Isle of Wight use M7 Energy storage use case

KPI Data	Unit	Baseline	Smart
Retailer Cost of Energy	£	1443.69	468.04
Avg cost of Energy Consumption	£/kWh	3.97	1.29

Table 3. Environmental KPI Results for Isle of Wight M7 energy storage use case.

KPI Data	Unit	Baseline	Smart
CO2 Emission	Kg	1454.38	471.51
CO2 Emission Reduction	kg	982.87	

The outcome from the overall inteGRIDy framework and tools performance are summarised below:

Isle of Wight

- Virtual Power Plant (VPP) for Advance Building Management System Control (ABMSC) has been delivered.

- Demand Side Management (DSM) services have also been delivered with energy supplier input.

Terni

- Evaluation of Terni plot use cases has shown that collaboration mechanism between the DSO and Microgrid strongly enhances energy efficiency of the grid, which can be replicated in other microgrids when a proper regulatory framework is put in place.

San Severino

- A state-of-the-art forecast of renewable productions and load needs has been put in place and can provide a short-term forecast of the power injections and estimating long term (up to one year) prediction.
- Small scale batteries have been deployed in final user premises, exploiting them for improving self-consumption and testing an innovative service stacking approach.

Barcelona

- Smart solution implementation resulted in a reduction of 10% of the primary energy consumptions and a reduction of 42 tons of CO_2 emissions.
- Through maximising self-consumption from battery storage systems and PV generation, a significant decrease of 15% in energy cost and a carbon emission reduction of 255.96 kg was achieved.

St Jean

- The tools deployed at the St Jean pilot focused on the accurate, human-centric demand flexibility definition and DR control implementation. The implemented strategies yielded very promising results in relation to the flexibility potential of the pilot users.
- The validation results reveal a tool of high potential and forecasting capabilities providing discrete and well accepted control automation to the end-users.

Nicosia

- Flexibility readiness of the users through ad-hoc tests and regular operation was performed.
- Despite multiple challenges faced, mostly on the user side, the Nicosia-Cyprus demo site managed to effectively test and prove the use cases, fulfilling the objectives of the project and verifying performance through platform-trackable and other derived metrics.

Lisbon

- Results of tests demonstrated in Lisbon indicated that measures in practice allow the reduction of consumption in periods of higher tariffs, due to the pivotal action of the photovoltaic generation.
- Energy stored thermally in the ice tanks is used whenever the generation is not enough to supply the building loads. Calculated KPIs demonstrate cost saving actions, enabling a downward trend of the

energetic consumption as a peak load reduction.

Xanthi

- The virtual storage system implemented in Xanthi pilot site resulted to at least 45% less usage of the backup and less operating costs for the evaluation period.
- The amount of energy consumed from the microgrid (DG production) shows a reduction of 410.334 kWh in the evaluation period of (March and April). This results to a reduced Retailer cost of 329.50 € from a baseline retailer cost of 637.25 €.

Ploiesti

- The results obtained at the demonstration site show the feasibility of implementing an Energy Integration Information System (EIIS) such as application for monitoring, forecasting and optimisation of consumption at end user and DSO level.
- Optimization and forecasting were implemented using historical data from first generation smart meters and machine learning. Energy consumption reduction of 27030 kWh was observed.

Thessaloniki

- DR schedules were generated daily via Implicit DR events for each residence. The results indicate a reduction in both the peak to average ration (PAR) and the peak reduction. In addition, a slight decrease in CO_2 emission is evident, mainly due to the decreased energy consumption, both in office level and building level.
- The effect of using BESS instead of DR, when installed within the premises of commercial buildings, is also considered, where the PAR was reduced from 2.36 to 2.34% due to inteGRIDy solution.

Conclusion

The goals and objectives of KPIs and use cases, as established within the activities of WP1 and WP8, have been evaluated, following the adopted methodology for the evaluation process.

Despite the changes that occurred in some pilots due to several reasons, such as the COVID-19 pandemic restrictions, leading to procedures taking longer than originally expected, the evaluation of use case objectives has not been significantly affected. However, there have been some minor changes in the KPIs across pilot sites to adapt and reflect the objective of smart solution implementations across board. Following the KPI evaluation of pilot use cases, the overall impacts and success of the different partner tools implemented within the respective pilot sites have been ascertained.

Overall, the implementation of smart solution technologies within the inteGRIDy project has significantly achieved the set objectives such as demand flexibility/Grid optimisation; reduction in energy consumption, cost optimisation, retailers' costs, and energy storage/EV, CO_2 emission reduction related to pilot site use cases.

References

[1]. inteGRIDy Consortium (2017) D1.4 inteGRIDy Global Evaluation Metrics and KPIs, http://www.integridy.eu/content/d14-integridy-global-evaluation-metrics-and-kpis

[2]. inteGRIDy Consortium (2019) D8.1 inteGRIDy Pilot Evaluation Methodology and Framework, http://www.integridy.eu/content/d81-integridy-pilot-evaluation-methodology-and-framework

About Teesside University

TEES are involved in the inteGRIDy project and provides the Neighbourhood Energy Management and Optimization (NEMO) tool for the Barcelona pilot use case. NEMO has an extended functionality of communication modules and optimisation and builds upon energy management technology developed and demonstrated as part of the DR-BOB and IDEAS project1. More specifically, for inteGRIDy, NEMO optimization and decision-making functionality was implemented to optimize the self-consumption of PV generation via charging and discharging of the Battery energy management system (BEMS) in the Barcelona pilot site.

Information about the authors

Dr Chris Ogwumike is a Research Associate in the School of Computing, Engineering and Digital Technology (SCEDT), Teesside University, with research interest in smart grid / smart energy applications, and energy optimisation.

Dr Tariq Ahmed is a Research Associate working on Smart Grid and Optimisation of Energy Systems of the future.

Dr Huda Dawood is a Senior Lecturer in Engineering in the School of Computing, Engineering and Digital Technology (SCEDT), Teesside University, with research interests and experience includes data analytics and using Artificial Intelligence Machine learning and deep learning for optimization and predictive control.

Mr Bjarnhedinn Gudlaugsson is currently an Early-Stage Researcher / a PhD Student (PhD title: Development of a Decision support tool based on Sustainability Assessment and System Dynamic Modelling for Assessing Energytransition and New Energy Technology Integration into an-Urban Energy System) at the School of Computing, Engineering and Digital Technologies (SCEDT) at Teesside University.

Acknowledgment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731268.