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DRIvE Project Unlocks Demand Response Potential with Digital Twins †

Laura Pérez [1], Juan Espeche [1], Tatiana Loureiro [1,*] and Aleksandar Kavgić [2]

[1] R2M Solution Spain, Calle Villablanca 85, Despacho 109, 28032 Madrid, Spain; laura.perez@r2msolution.com (L.P.); juan.espeche@r2msolution.com (J.E.)
[2] Typhoon HIL, Bajci Zilinskog bb, 21000 Novi Sad, Serbia; aleksandar.kavgic@typhoon-hil.com
* Correspondence: tatiana.loureiro@r2msolution.com; Tel.: +34-918-276-597
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Abstract: DRIvE (Demand Response Integration Technologies) is a research and innovation project funded under the European Union's Horizon 2020 Framework Program, whose main objective is unlocking the demand response potential in the distribution grid. DRIvE presented how the use of digital twins de-risks the implementation of demand response applications at the "Flexibility 2.0: Demand response and self-consumption based on the prosumer of Europe's low carbon future" workshop within the conference "Sustainable Places 2020". This workshop was organized to cluster and foster knowledge transfer between several EU projects, each developing innovative solutions within the field of demand response, energy flexibility, and optimized synergies between actors of the built environment and the power grid.

Keywords: demand response; smart grids; distributed schemes; multi-agent systems; flexibility management; blockchain technology; digital twins; control algorithms; cyber-security

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1. Introduction

It is widely recognized that increasing flexibility is key for the reliable operation of future power systems with very high penetration levels of variable renewable energy sources (RES). Flexibility is the ability of a power system to maintain continuous service in the face of rapid and large swings in supply or demand. The most significant source of flexibility in a future scenario with high penetration of RES is demand response (DR).

"Flexibility 2.0: Demand response and self-consumption based on the prosumer of Europe's low carbon future" was a workshop within the conference "Sustainable Places 2020" [1] where seven Horizon 2020 projects presented and benchmarked their research on DR and self-consumption based on the prosumer of Europe's low-carbon future. The workshop was aimed at fostering knowledge transfer between the participating EU H2020 projects, developing innovative solutions within the field of demand-side flexibility. The problems being solved and technologies developed facilitate optimized synergies between actors of the built environment and the power grid.

At this workshop, the EU-funded H2020 DRIvE (Demand Response Integration Technologies) project [2] showed the benefits of using digital twins to unlock the DR potential in a low-risk setting, as recently published in the European Energy Innovation magazine [3]. By unlocking flexibility via DR, the DRIvE project addresses the intermittent generation from distributed renewable energy sources, which is one of the key challenges of the energy transition as it can cause grid issues at all levels. In particular, DRIvE unlocks the distributed flexibility potential in the medium- and low-voltage grids, which has little precedent in the market to date. The project, ending in November 2020, is in the stage of final validation activities, result assessment, and wider commercial uptake of the project technologies, as well as exploration of pathways for additional innovation.

2. About DRIvE

DRIvE [4] links together cutting-edge science in multi-agent systems (MAS), forecasting, and cyber-security with emerging innovations making first market penetration in EU DR markets. In doing so, near-market solutions are strengthened with innovative functionalities that support a vision of an "internet of energy" and "collaborative energy network". From the research side, MAS will move closer to real time operations and progress from a limited number of assets toward decentralized management of a larger number of assets providing DR services to prosumers, grid stakeholders, and distribution system operators.

DRIvE aims to unlock the DR potential of residential and tertiary buildings in the distribution grid, representing 70% of the total DR potential. To address this, DRIvE project has developed a full-fledge platform bridging seamlessly the value chain from planning and design of distributed assets/buildings towards optimal operations in the next generation of smart grids, paving the way towards a fully deployed DR market in the distribution network [5].

The main objectives of the project are (1) unlocking DR potential in residential and tertiary buildings through low-cost solutions that are universally interoperable, while integrating innovative load prediction and optimization algorithms; (2) optimization of distribution grid flexibility through an integrated multi-agent based DR platform for aggregators integrating last advances in distributed real-time control architecture, artificial intelligence, and communications; (3) demonstration of secure communication through the design and development of cyber-security components for smart grids; and (4) engaging customers to participate in DR programs through a consumer portal [4].

DRIvE has demonstrated the effectiveness of the proposed flexibility management platform through a wide set of validation activities involving six demonstration sites and globally covering all services within the DR value chain [4].

3. DRIvE Platform

DRIvE project has developed a fully integrated ICT infrastructure consisting of interoperable DR-enabling and energy management solutions for residential and tertiary buildings and a platform for effective and secure management of energy flexibility at the level of the distribution grid. The cloud+gateway infrastructure provided by DRIvE platform allows for the aggregation of distributed assets within a single environment, making them controllable for DR programs and for providing ancillary services (e.g., frequency and voltage regulation, power quality support) [3,4].

The platform pretends to make available 20% of load in residential and tertiary buildings for use in DR schemes, resulting in up to 30% cost-saving (price-based DR) and also maximizing revenue for prosumers (incentive-based DR). On the other hand, DRIvE aims for a minimum 25% increase of renewable hosting capacity at the distribution grid, and up to 30% of overall reduction of capital (CAPEX) and operational (OPEX) expenditures for distribution system operators (DSOs). The platform allows the grid congestion issues to be managed by changing operational parameters of the flexibility assets, avoiding the need for grid reinforcement.

In particular, DRIvE offers in-building services for the prosumers, such as time-of-use (ToU) optimization and kWmax control (control of the maximum load), among others, as well as flexibility services to different parties: the balance responsible party (BRP), the distribution system operator (DSO), and the transmission system operator (TSO). DRIvE platform allows aggregators to reconfigure assets (portfolio management); offers congestion management, voltage control, and power quality support (e.g., reactive power control) for DSOs; and also provides frequency containment reserve (FCR) and frequency restoration reserve (FRR) services for TSOs [6].

DRIvE project has validated the performance of its platform and flexibility services through pilot demonstrations ranging in all stages of the energy value chain, from large-scale generation plants to residential community and tertiary buildings. Although the validation scenarios were devised for the DRIvE platform and test sites, the scenarios should be universally applicable to other sites and other remote-controlled devices. The DRIvE project has used three different modes of validation activities: (1) offline simulation; (2) real-time cyber and cyber-physical emulation; and (3) physical testing—which allow for a safe optimization and testing of the DR services before deployment at the site [6].

The biggest innovation in this respect is the introduction of the cyber-physical emulation as a testing mode, which means that multi-agent system and DR logic can be fully tested in complete safety because this kind of testing implies that local energy gateways are connected to high-fidelity models of controlled devices, providing direct insight into the behavior of the DRIvE logic and algorithm but in the safety of virtualized power (devices are real-time models) [6].

Physical testing of the DRIvE platform has been performed at four demo sites in the Netherlands: DEVO district, Giessenwind wind farm, ADO Stadium, and Woerden district, and one site in Spain: COMSA head office building. At the four latter sites, hybrid, cyber-physical testing with digital twins has also been performed, with the aim of de-risking the physical testing and, hence, the subsequent implementation and investment [3].

4. Hybrid, Cyber-Physical Testing with Digital Twins

A key piece of the validation process is digital twin and control hardware in the loop (C-HIL) testing, which accelerates implementation by directly addressing integration issues and providing early validation before beginning costly physical tests. As the DRIvE project closes its final stage of validation, the first results show significant potential to unlock flexibility from generation assets [3].

The Giessenwind demonstration site, featuring transmission lines, a transformer station, and battery storage for excess energy from wind generation, has provided an excellent opportunity to benchmark and validate the potential flexibility available from voltage control, frequency control testing, and congestion management actions via this single platform approach. Results from FCR and congestion management tests have shown that current equipment can utilize these algorithms, significantly reducing the need for new CAPEX installations for grid reinforcement by up to 20%.

This approach has also simplified the integration stages of these algorithms. During the model validation process with the digital twins, bugs in MODBUS maps and other communication issues can and have been identified quickly and repaired, which are issues that could significantly harm physical equipment if deployed directly to the devices. This improves scaling capacity in a low-risk setting, minimizing the risks that real devices may face due to human errors [3].

In addition to the direct energy savings results, easy and reliable virtual testing procedures allow for extreme scenario and future capability testing that would otherwise not be cost-effective in physical testing. In the Giessenwind site, this included analyzing the effects of islanding and highly irregular frequency scenarios. C-HIL digital twins have proved important in applications at other demonstration sites as well, with the results of full algorithm validation tests on ToU energy bill optimization and kWmax consumption serving as a critical step in assuring building managers and owners that these new DR control actions perform as intended and will not negatively impact existing systems [3].

The tests at Giessenwind site have shown that, by using digital twin C-HIL validation, novel DR capabilities can be tested in a low-risk setting earlier in the production process, saving time and potentially dangerous risks associated with physical piloting. Scenario validation with digital twins is an excellent means to safely gather information on system performance for new applications with little precedent in the existing market.

Such low-risk tests are also being performed for residential and tertiary building applications. For example, at the Woerden demonstration site, there are 39 smart, energy-efficient houses with solar panels and controllable inverters, and a large district battery. With regard to tertiary building applications, the DRIvE project has performed tests at ADO Stadium, where solar panels, an energy storage system, and an electric vehicle (EV) charging point have been installed; and at COMSA headquarters, which is a fully electrical building that is equipped with solar panels, battery, and controllable HVAC units, connected to an advanced energy management system. At these sites, the models for congestion management, frequency control, voltage control, and power quality support were validated.

Hybrid cyber-physical testing with C-HIL digital twins were proven to be crucial in the DRIvE demo sites to de-risk the implementation of the proposed platform, as well as to provide confidence to the building owners and site operators that no problems would arise from unplanned behavior of the control algorithms (e.g., damage to the physical devices, end-user interaction problems).

This is possible since the digital twin uses the same infrastructure as in the real application. The DRIvE logic, the execution platform, and the hardware (clusters of local energy gateways) are the same as in the physical testing but control the validated digital twin models of all the real assets in the demo sites. Historical real-time data feed the emulation. In order to ensure the fidelity of the digital twins, it is necessary to validate that the models behave like the real assets.

5. Benefits of Digital Twins for Demand Response

At the Flexibility 2.0 workshop, during the Sustainable Places 2020 conference [1], the relevance of digital twins as a tool to unlock the potential of DR solutions was highlighted. The main benefits identified are presented below:

5.1. De-Risking Implementation and Investment

- Exhaustive testing and validation of control algorithms in the emulation.
- Full confidence in final implementation of new services at a physical pilot site.
- Interoperability issues solved in the emulated domain (real and emulated protection relays).
- Standardized tests for pre-certification and adherence to grid codes.

5.2. Benchmarking and Qualification of Suppliers/Vendors

- Parametrize automated test scripts and perform A/B or what-if tests, from the technological or financial perspective.
- Week- or month-long test runs for assessing, e.g., DR services, ancillary services, trading in the flexibility market.

5.3. Exploring New Business Opportunities

- Using digital twins to explore new or additional services for DSOs, BRPs, and/or TSOs, e.g., power quality support (THD mitigation, reactive power support, etc.).
- Modeling for financial benefits of various services for various types of portfolios.
- Safe and fast demonstration to stakeholders and prospects (DSOs/BRPSs/TSOs).

5.4. New Applications of DR Digital Twins

- Using digital twins of DR sites to generate clean data as training sets for ML/AI (machine learning/artificial intelligence) cyber-security.
- Streamlining the work of system integrators and aggregators—with easily parameterizable digital twin models, system integrators and aggregators can perform digital integration first and be confident in 100% error-free commissioning at the physical site.
- Digital shadows for lifecycle management of DR assets/sites.

6. Conclusions

During the workshop on "Flexibility 2.0: Demand response and self-consumption based on the prosumer of Europe's low carbon future", at the Sustainable Places 2020 conference [1], the DRIvE project presented the use of hybrid cyber-physical testing with digital twins as the cornerstone to unlock DR potential and de-risk its implementation, particularly in medium- and low-voltage grids.

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References

1. Sustainable Places Website. Available online: www.sustainableplaces.eu/ (accessed on 11 November 2020).
2. European Commission, CORDIS, EU Research Results. Demand Response Integration Technologies: Unlocking the DR Potential in the Distribution Grid. Available online: cordis.europa.eu/project/id/774431 (accessed on 11 November 2020).
3. Communication, European Energy Innovation. DRIvE Unlocks Demand Response Potential and De-Risks Implementation. European Energy Innovation Online Magazine, Summer 2020, p. 22. Available online: europeanenergyinnovation.eu/OnlinePublication/Summer2020/mobile/index.html (accessed on 9 November 2020).
4. DRIvE Website. Available online: www.h2020-drive.eu (accessed on 11 November 2020).
5. Loureiro, T.; Espeche, J.; Vinyals, M.; Stecchi, U.; Tzovaras, D.; Ioannidis, D.; Geysen, D. Distributed Schemes, Innovative Solutions for Smart Grids: P2P, Multi-Agent Systems & Blockchain. *Proceedings* **2019**, *20*, 5, doi:10.3390/proceedings2019020005.
6. Kavgic, A.; Bastiaenses, J.; Smets, E.; Costa, S.; Alemeida, M.; Maryama, V.; Sterling, R. D7.1 Validation plan. *Zenodo* **2019**, doi:10.5281/zenodo.3360707.