COLORS

CONTEXTUAL LOAD FLEXIBILITY REMUNERATION STRATEGIES

White Book

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COLORS explores business models and market structures for intensive and efficient use of distributed energy resources with focus on demand response. Taking into account the context created by the photovoltaic and wind generation, the different periods of the day and week, the temperature, and electricity market prices, different innovative tariff and remuneration schemes and strategies are developed. A COLORS demand response platform was developed in order to test different options for the remuneration of consumers participation in demand response programs, for both the aggregator and the consumer. Dynamically defined clusters of consumers are established according to the context. A simulation platform combining multi-agent and physical emulation enables the realistic validation of the project results also assessing increased smart grid efficiency and lower pollutant emissions and energy costs.

Introduction

This white book provides up-to-date insights on several aspects of Demand Response (DR), or load flexibility, as well as research questions for future work. Divided in several sections, this book starts with a section on back to basics. Then, companies and DR service providers are listed. After that, projects addressing effective consumer response and demand response flexibility are identified. Lists of relevant reports and documents from European Commission are then provided. In the second-last section, future research questions are identified. Finally, for further reading, the last section includes the COLORS project list of publications.

Back to basics

The demand response concept has been changing over years. Broadly defined, demand response refers to the active participation of a consumer in the electricity market checking and responding to prices of electricity that change from period to period, and accounting incentive payments. This period can vary from months (when energy efficiency is studied) to a few minutes (when real-time pricing is applied). Demand response has been defined in United States Department of Energy, in 2006, as follows:

"Changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."

The participation of a consumer in a DR program or event is always a contribution to the reduction on the need of electricity in a specific period, in a specific area. This area can be seen as the whole power system or be related with the special case of transmission congestion in a small area. Consumers can react to electricity prices or DR incentive-based events in three ways. Firstly, one have the possibility of “Foregoing” which corresponds to reducing electricity usage at times of high prices or DR program events, without using it later. It can cause temporary loss of amenity or comfort. Second, the “Shifting” corresponds to the rescheduling of the electricity usage from periods of high prices or DR programs events to other periods. The service or

amenity is re-established in the subsequent or rescheduled period. This reschedule can have costs regarding overtime payment or productivity losses due to the required adjustments in the production process. Finally, “Onsite generation”, in which consumers who have an onsite or backup emergency generator may respond by using it to satisfy some or all of their or others consumption needs.

The use of any of the referred strategies causes inconvenience, discomfort, and/or loss of productivity in the buildings occupants or in the laboring process. Such factors should be included in the cost-benefit analysis that supports DR decisions, even if some of them are not directly accounted.

Price-based demand response is related to the changes in energy consumption by customers in response to the variations in their purchase prices. This group includes Time-Of-Use (TOU), Real Time Pricing (RTP) and Critical-Peak Pricing (CPP) rates. For different hours or time periods, if the price varies significantly, customers can respond to price variations with changes in energy use. Their energy bills can be reduced if they adjust the time of the energy usage exploiting the lower prices in some periods and/or reduce consumption when prices are higher. Currently, the response to price-based demand response programs by adjusting the time of consumption is entirely voluntary.

Incentive-based demand response includes programs that give customers fixed or time varying incentives in addition to their electricity rates. These can be established by utilities, load-serving entities, or by a regional grid operator. Some of these programs penalize customers that fail the contractual response when events are declared.

Another important demand-side resource that can be considered independently, but not necessarily disconnected from the above described DR programs is the energy efficiency.

Since 2006, the paradigm of power systems and electricity markets has been constantly changing. According to each specific context and reality, distinct approaches for DR programs classification have been proposed. One of the most relevant associations in the field of DR is the “Open Automated DR Aliance – OpenADR” (http://openadr.memberclicks.net). A draft document published in 2014 proposes the classification of DR according to 6 distinct program types: Critical Peak Pricing, Capacity Biding Program, Residential Thermostat Program/Direct Load Control, Fast DR Dispatch/Ancillary Services Program, Electric Vehicle (EV) DR Program, and Distributed Energy Resources (DER) DR Program. Some of the classifications established by the United States Department of Energy are still being used. However, some different classifications have been added according to the more recent and increasingly relevant and impacting resources, as the case of electric vehicles and distributed energy resources, namely in the context of smart grids.

The above referred classification approaches refer to the scope and motivation of DR programs implementation. It is also important to find ways of classifying the DR programs and events according to their implementation further than the scope and motivation. An approach to such need has been published by the North America ISO and RTO association. The US is the country in the world with the largest implementation of DR, where the regulatory orders and reports from FERC concerning the use of DR play a relevant role.

For last, Europe has been referring to demand response programs broadly dividing them in Implicit DR and Explicit DR, corresponding to price-based DR and incentive-based DR. Flexibility is another name for the same purposes.

Companies and DR Service Providers

Demand-side flexibility can be enabled by new business models like aggregator, virtual power plants, and other distributed energy resource platforms. But the majority of the currently available options rely on conventional load reduction programs rather than automated or dynamic system services. Adoption of new technology, including smart meters and controls, as well as supporting legislative and regulatory frameworks, are necessary for the success of novel business models. The following list presents some we stablished business in this sector and how they are acting to support/change/improve the system.

1. Ampere – is a residential storage developer, which was bought by Repsol that also provides flexibility services by managing their batteries through a VPP. This company offers advanced software solutions for energy management. https://ampere-energy.com/pt
2. BuildingIQ – is a company that offers a software, which claims to help building owners and operators worldwide to low their energy use, increase building operations efficiency, and improve occupant comfort. https://buildingiq.com/
3. Cooper Power Systems – is a company that offers a large selection of products and services, going from fuel-efficient systems, to power chain management tools and components that guide commercial aircraft. http://www.cooperpower.com/us/en-us.html
4. CPower – is a company that helps organizations in subjects related with distributed energy resources by working with distributed generation, energy storage, energy efficiency, demand response and peak demand management. https://cpowerenergymanagement.com
5. Enel X – is a company that was used to be known as ENErNOC and World Enerrgy Solutions. It works with demand response, energy procurement services, distributed energy resources, energy storage solutions and utility bill management. They provide solutions to optimize how customers buy energy and when and how much they use it. https://www.enelx.com/n-a/em
6. ENERES – is a company that offer solutions to electric power issues on behalf of customers and total support for electric power business by offering energy-distribution services for power retailers and corporate power consumers. https://www.eneres.co.jp/english
7. Energy2market – is a company that offers route to market services, flexibility monetisation in trading and balancing markets, price-optimised power plant deployment, power plant monitoring, demand response in control energy markets, demand side management, peak shaving and peak shifting, load control (e-mobility), energy supply (selected markets), optimised storage deployment, flexibility trading on traditional and balancing energy markets, load control (e-mobility), white label direct marketing, white label flexibility marketing and VPP as a service. This aggregator has more than 4500 connected units and was acquired by EDF, a German VPP company. https://www.e2m.energy/en/start-en.html
8. Engie – this company acquired Tiko, a Swiss residential VPP, and Kiwi Power, an UK demand response operator. It offers solutions for, what they call, cities of the future and industries of the future. This organization is a global player in the energy and services sector. https://www.engie.pt/
9. EPS – is a company that offers hardware and software in a real-time energy management system. The company focuses on curbing power at industrial sites, but it also landed an

agreement with the Energias de Portugal to provide its software to the utility's customers in Portugal and Spain. http://www.epsway.com

10. Go Electric – offers solutions in many areas as commercial, industrial, military, electric utility, besides uninterruptible power, microgrid control, energy efficiency, and demand response. It received investments from Total. https://goelectricinc.com/
11. Honeywell – is a company that claims to help utilities by identifying and recruiting the right customers and then developing shed strategies tailored to both the customer and the needs of the utility. They do this by offering services as security, edge devices, networks, modular applications, enterprise platforms, electrification, customer engagement, program marketing, program management, transactive energy, virtual power plants, fast frequency response, demand response, and electrification. https://buildings.honeywell.com/us/em
12. Itron – is a company also known as Comverge. It offers smart networks, software, services, meters, and sensors so that, utilities and cities in more than 100 countries can manage their energy and water. https://www.itron.com/na
13. Kaluza – is a subsidiary of OVO energy that was launched in 2019. It offers services for energy operation systems and demand response. It optimize individual devices to add new flexibility into the system. It also offers a range of demand-side flexibility services as residential battery load management, residential heat storage, and a field trial of smart EV-charging in London. https://www.kaluza.com/
14. Limejump – is a company that was acquired by Shell and works closely with renewable asset owners, buying their energy and then selling it in to the UK's grid. It works as a technology platform that manages a large renewable energy network and deliver clean energy to businesses and households, using renewables and stored energy when it's needed to meet demand. https://www.limejump.com/
15. Optimum Energy – is a company that offers an optimum Energy's HVAC optimization software solution to all types of organizations around the world, from manufacturers to hospitals, universities, office buildings, labs, data centers and more. https://optimumenergyco.com/
16. Oracle – also known as Opower, helps managing peak demand through behavioral science. https://www.oracle.com/industries/utilities/opower-energy-efficiency/what-is-opower/
17. Schneider Electric – is a big organization that acquired SureGrid subsidiaries (Luminous Power Technologies Pvt Ltd., invensys, SolveIT Software, APC, Areva T&D, BEI Technologies, Cimac, Citect, Clipsal, ELAU, Federal Pioneer, Merlin Gerin, Merten, Modicon PLC, Nu-Lec Industries, PDL Group, Power Measurement, Square D, TAC, Telemecanique, Telvent, Gutor Electronic LLC, Zicom, Summit, Xantrex). It offers services in many areas, like building and home automation, switches and sockets, industrial safety systems and control systems, electric power distribution, electrical grid automation, smart grid, critical power & cooling for datacenters, among others. https://www.se.com/pt/pt/
18. Siemens – has SureGrid, which is an energy solutions provider that can manage building's energy by monitoring and controlling major energy consuming devices, such as HVAC, lighting, refrigeration, signage and more, SureGrid technology enables each building to dynamically interact with the electrical grid based on local business rules and real-time asset and environmental conditions. https://new.siemens.com/us/en/products/buildingtechnologies/energy/energy-efficiency/suregrid.html

Considering the 18 companies presented in this section, Table 1 summarizes a list of companies presented as DR providers and aggregators. Some were already presented before based on its dimension, and others are being introduced in Table 1.

Table 1. List of companies presented as DR providers and aggregators

#	Name	Link
1	Actility	https://www.actility.com/
2	Advanced Microgrid Solutions	www.advmicrogrid.com
3	AutoGrid Systems	www.auto-grid.com
4	Chai	chaienergy.com
5	EDF Trading	www.edftrading.com/
6	EDP - Energias de Portugal	https://www.edp.com
7	Empower IM Oy	https://www.empower.eu/
8	Enel X	https://www.enelx.com
9	EnergyHub	www.energyhub.com
10	Enersponse	https://www.enersponse.com/
11	Enerwise Global Technologies	cpowerenergymanagement.com
12	Engie Storage Services NA	www.engiestorage.com/
13	Fortum	https://www.fortum.com/
14	Gen-I	https://gen-i.si/
15	Good Energy	https://www.goodenergy.co.uk/
16	IPKeys Power Partners	ipkeyspowerpartners.com
17	Leapfrog Power	www.leap.ac
18	Next Kraftwerke	https://www.next-kraftwerke.com/
19	NRG Curtailment Solutions	demandresponse.nrg.com
20	Oekostrom	https://oekostrom.at/mein-oekostrom
21	OhmConnect	www.ohmconnect.com
22	Olivine	olivineinc.com
23	RE-Pro	http://re-pro.eu/
24	Shell Energy	www.shell.com/
25	Stem	www.stem.com
26	Sunrun	www.sunrun.com
27	Svensk Solenergi	https://svensksolenergi.se/
28	Tesla	www.tesla.com/commercial
29	Trane Grid Services	www.trane.com
30	Voltus	https://www.voltus.co/

Moreover, Energy Ring (www.energyring.pt/) presents itself as a DR facilitator.

Projects addressing effective consumer response and demand response flexibility

This section presents the most recent and relevant projects that addresses/addressed effective consumer response and demand response flexibility. The final list contemplates 13 European projects from 2015 until today.

1. CROSSBOW - CROSS BOrder management of variable renewable energies and storage units enabling a transnational Wholesale market
   From – to: 1 November 2017 - 30 April 2022
   Coordinated by: ETRA INVESTIGACION Y DESARROLLO SA (Spain)
   Description: CROSSBOW aims to foster cross-border management of variable renewable energies and storage units. The objective is to demonstrate a number of different, though complementary, technologies. Results were evaluated by 8 TSOs in Easter Europe, grouped to form clusters that is going to validate each of the projects outcomes.

2. DREAM-GO - Enabling Demand Response for short and real-time Efficient And Market Based smart Grid Operation - An intelligent and real-time simulation approach
   From – to: 1 February 2015 - 31 January 2019
   Coordinated by: INSTITUTO POLITECNICO DO PORTO (Portugal)
   Description: Efficient power systems require the optimal use of the available resources to cope with demand requirements. Demand Response programs with adequate business models can leverage demand flexibility both on centralized and distributed models. DREAM-GO aimed to create a framework with the required methods and solutions to facilitate the adoption of the results in final applications.

3. DRIMPAC - Unified DR interoperability framework enabling market participation of active energy consumers
   From – to: 1 September 2018 - 31 August 2022
   Coordinated by: ETHNIKO KENTRO EREVNAS KAI TECHNOLOGIKIS ANAPTYXIS (Greece)
   Description: Buildings are a vast, yet untapped source of energy demand flexibility that can provide invaluable services to the energy system. The lack of a technological framework that can connect the multitude of buildings and building systems has led to reluctance of energy consumers to participate in demand response programs. DRIMPAC offers a comprehensive solution to empower consumer to become active participants in the energy markets.

4. DRIVE - Demand Response Integration tEchnologies: unlocking the demand response potential in the distribution grid
   From – to: 1 December 2017 - 30 November 2020
   Coordinated by: R2M SOLUTION SPAIN SL (Spain)
   Description: The DRIvE project delivered a fully-integrated, interoperable and secure DR Management Platform for Aggregators with advanced hybrid forecasting, optimization, fast-response capabilities and enhanced user participation components.

5. DOMINOES - Smart Distribution Grid: a Market Driven Approach for the Next Generation of Advanced Operation Models and Services
   From – to: 1 October 2017 - 30 June 2021
   Coordinated by: ENERIM OY (Finland)

Description: DOMINOES aimed to enable the discovery and development of new demand response, aggregation, grid management and peer-to-peer trading services. The project addressed all the requirements of the LCE-01-2017 call for local energy market solutions.

6. eDREAM - enabling new Demand REsponse Advanced, Market oriented and Secure technologies, solutions and business models
   From – to: 1 January 2018 - 30 June 2021
   Coordinated by: ENGINEERING - INGEGNERIA INFORMATICA SPA (Italy)
   Description: Demand Response (DR) represents a valid alternative to grid reinforement for electricity Distribution System Operators (DSOs). Project aims to optimize aggregated system services flexibility provisioning to DSOs. eDREAM will develop and make available a novel near real time DR scalable secure secure blockchain-driven framework.

7. FLEXICIENCY - energy services demonstrations of demand response, FLEXibility and energy effICIENCY based on metering data
   From – to: 1 February 2015 - 31 January 2019
   Coordinated by: E-DISTRIBUZIONE SPA (Italy)
   Description: Open European Market Place for standardized interactions among all the electricity stakeholders. The proposed virtual environment will empower real customers with higher quality and quantity of information. Accessibility of metering data in a standardized and non-discriminatory way will facilitate the emergence of new markets for energy services.

8. FLEXCoop - Democratizing energy markets through the introduction of innovative flexibility-based demand response tools and novel business and market models for energy cooperatives
   From – to: 1 October 2017 - 31 January 2021
   Coordinated by: FRAUNHOFER GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V. (Germany)
   Description: FLEXCoop is an end-to-end Automated Demand Response Optimization Framework. It enables the realization of novel business models for energy cooperatives. This is achieved via automated, human-centric demand response schemes with the participation of appropriately selected residential prosumers.

9. HOLISDER - Integrating Real-Intelligence in Energy Management Systems enabling Holistic Demand Response Optimization in Buildings and Districts
   From – to: 1 October 2017 - 31 March 2021
   Coordinated by: FUNDACION TECNALIA RESEARCH & INNOVATION (Spain)
   Description: HOLISDER enable significant energy costs reduction (~45%) at the consumer side, while introducing buildings as a major contributor to energy networks' stability. The framework was validated in 4 large-scale demonstrators/pilot sites, located in Greece, UK, Finland and Serbia.

10. NOBEL GRID - New Cost Efficient Business Models for Flexible Smart Grids
    From – to: 1 January 2015 - 30 June 2018
    Coordinated by: ETRA INVESTIGACION Y DESARROLLO SA (Spain)
    Description: NOBEL GRID develop, deployed and evaluated advanced tools and ICT services for energy DSOs cooperatives and medium-size retailers. The results was demonstrated and validated in real world environments with active involvement of all the actors to ensure that all consumers benefit from cheaper prices and more secure and stable grids.

11. RESPOND: integrated demand REsponse Solution towards energy POsitive NeighbourhooDs
    From – to: 1 October 2017 - 30 June 2018

Coordinated by: ETRA INVESTIGACION Y DESARROLLO SA (Spain)
Description: RESPOND aimed to deploy and demonstrate an interoperable, cost effective, user centred solution for a seamless integration of cooperative DR programs into the legacy energy management systems. The RESPOND solution was capable of delivering a cooperative demand response at both building and district level.

12. Sim4Blocks - Simulation Supported Real Time Energy Management in Building Blocks
From – to: 1 October 2017 - 30 September 2020
Coordinated by: FENIE ENERGIA SA (Spain)
Description: SIMBLOCK will develop innovative demand response (DR) services for smaller residential and commercial customers. It will implement and test these services in three pilot sites and transfer successful DR models to customers of Project partners in further European countries. SIMBLOCK's main objectives are to specify the technical characteristics of the demand flexibility that will enable dynamic DR.

13. Spatialec - Developing methods to model local area temporal domestic electricity demand
From – to: 1 December 2017 - 31 October 2020
Coordinated by: UNIVERSITY OF SOUTHAMPTON (United Kingdom)
Description: SIMBLOCK developed innovative demand response (DR) services for smaller residential and commercial customers. It implemented and tested these services in three pilot sites and transfered successful DR models to customers of Project partners in further European countries. SIMBLOCK's main objectives were to specify the technical characteristics of the demand flexibility that would enable dynamic DR.

It is also informative to look at the project results from BestRES - Best practices and implementation of innovative business models for Renewable Energy Aggregators: The main objective of the BestRES project was to improve the role of renewable energy aggregators in future electricity market design. It was funded by the Horizon 2020 EU Research and Innovation programme and involved 11 partner organizations that are active in nine different European countries. The project started in March 2016 and lasted three years.

List of reports

This section presents a list of reports addressing effective consumer response and demand response flexibility. This corresponds to an extensive and much focussed list of documents with the intention to facilitate the access to state of the art knowledge on this subject.

[1] Crawley, C., Johnson, C., Calver, P. and Fell, M.J. 2021. Demand response: success isn't just about numbers. CREDS Policy brief 016. Oxford, UK: Centre for Research into Energy Demand Solutions.
[2] IEA. (2020). *Demand Response*. Retrieved from https://www.iea.org/reports/demand-response
[3] IEA (2021), Demand Response, IEA, Paris https://www.iea.org/reports/demand-response
[4] IEA (2020), Tracking Demand Response 2020, IEA, Paris https://www.iea.org/reports/tracking-demand-response-2020
[5] IRENA (2019), Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables.

[6] IRENA. (2019). Demand-side flexibility for power sector transformation. In *Analytical Brief*. Retrieved from /publications/2019/Dec/Demand-side-flexibility-for-power-sector-transformation
[7] International Renewable Energy Agency, Abu Dhabi (ISBN 978-92-9260-111-9)
[8] Moon, N., D. Rogers, and S. McHugh, Energy Market Investigation: A report for the Competition and Markets Authority by GfK NOP, Feb. 2015.
[9] NEDO, Implementation Report for Smart Community Demonstration Project in Greater Manchester, UK. 2017.
[10] UK Power Networks, Energywise SDRC 9.5 Report: The Energy Shifting Trial Report. 2018: London.
[11] Hallberg, P. "EURELECTRIC Views on Demand Side Participation: Involving Customers, Improving Markets, Enhancing Network Operation". https://www.ceer.eu/
[12] E. Union, "Results achieved in the Swedish demonstration," no. 2019, 2020.
[13] Flexiciency, "Final Report D11.6," no. 2019, pp. 1–27, 2019.
[14] E. Union, "FLEXIbility and energy effiCIENCY based on metering data D11.5 – Final project conference proceedings to disclose the consortium conclusions and recommendations Document Information," no. 2019, 2020.
[15] E. Union, "D9.3 – Report on the Results achieved in the Austrian and Pan-European Demonstrations Document Information," no. 2019, pp. 1–53, 2020.
[16] E. Union, "FLEXibility and energy efficIENCY based on metering data Document Information," no. 2016, pp. 1–27, 2020.
[17] G. Vaccarone, "FLEXibility and energy efficIENCY based on metering data Report on the integration of the infrastructure with the new Services / Aggregator platforms D7.4 – Report on the integration of the infrastructure with the new Services / Aggregator platforms for," no. 2018, pp. 1–25, 2020.
[18] E. Union, "Assessment of the business models developed in the D6.3 – Assessment of the business models developed in the French demo," no. 2019, 2020.

List of documents from EC

This section presents an exhaustive list of European Commission documents addressing effective consumer response and demand response flexibility. This corresponds to an extensive and much focused list of documents with the intention to facilitate the access to state of the art knowledge and legislation on this subject in Europe.

[19] European Union Agency for the Cooperation of Energy Regulators and the Council of European Energy Regulators, "Annual Report on the Results of Monitoring the Internal Electricity and Natural Gas Markets in 2020. Energy Retail Markets and Consumer Protection Volume," 2021.
[20] European Commission, ASSET Study on Regulatory priorities for enabling Demand Side Flexibility. Brussels, 2020.
[21] European Smart Grids Task Force Expert Group 3. (2019). Demand Side Flexibility: Perceived barriers and proposed recommendations. (April), 1–50.
[22] T. Serrenho and P. Bertoldi, Smart home and appliances: State of the art. 2019.
[23] EU Commision DG Energy, "Impact assessment study on downstream flexibility, price flexibility, demand response & smart metering," no. July 2016, p. 192, 2016.
[24] Council of European Energy Regulators, Sample answers, p.3. Brussels, 2014.

[25] Council of European Energy Regulators, CEER Advice on Ensuring Market and Regulatory Arrangements help deliver Demand Side Flexibility, p.37. Brussels, 2014.
[26] Council of European Energy Regulators, Ensuring Market and Regulatory Arrangements help deliver DemandSide Flexibility, p.11. Brussels, 2014.
[27] C. From and T. H. E. Commission, "Delivering the internal electricity market and making the most of public intervention," Commun. From Eur. Comm., no. 7243 final, p. 19, 2013
[28] Council of European Energy Regulators, Regulatory and Market Aspects of Demand-Side Flexibility, p.55. Brussels, 2013.
[29] Council of European Energy Regulators, Guidelines on CEER's Public Consultation Practices, p.6. Brussels, 2012.

Future research questions

During the execution of COLORS project, several research questions have been answered, with adequate methodologies published in relevant scientific literature. In this section are listed questions for future research, while some insights are provided about the departing point upon COLORS results.

What are the incentives that consumers are seeking in DR?

The COLORS team found that different consumers can be motivated in different ways. For some of them, monetary incentive can be the major aspect. For others, discount in other goods and services can be interesting. In fact, a combination of both should be offered to the consumers to take their best decision, always keeping them free to change their decision.

In what extent the active participation is against comfort?

The most the participation in DR events, the higher effort from consumers can be demanded to make the participation effective. This can cause loss of comfort. In COLORS was found, and methodologies have been proposed, that learning approaches can learn the consumer behavior, providing intelligent decision according to the consumer previous responses. These learning approaches require more effective testing and validation in the field.

How can smart appliances support consumers participation in DR events?

Whether the consumer defines a set of rules, or an energy management system learn the consumer preferences, smart appliances can work in a way that automated response is provided to each DR event, increasing the consumer performance. Interoperability and privacy data issues need to be addressed.

Which innovative aggregation approaches can be implemented?

While in COLORS several approaches for DR resources aggregation have been established, those should be updated with additional features related with consumers constraints related to the participation, as the modelling of the consumer comfort features evolves in the literature.

Implicit or explicit DR?

In the beginning of COLORS project, DR programs were mainly divided in price-based and incentive-based. During the project, implicit and explicit DR appeared. In fact, while most of the consumers are well motivated by monetary incentives according to the performance, it is hard to define the amount of remuneration to attribute to each consumer in each context, as the consumer has difficulty in defining it. In this way, according to the different contexts, combinations of implicit and explicit DR should be defined.

Individual or group remuneration?

When activating DR, i.e. when calling consumers to respond to an event, an aggregator or system operator must define ways to identify the consumers that will be activated. The same aspect happens with the remuneration. In the limit, a remuneration scheme can be defined individually for each consumer. However, it can be difficult in practice and raise discussion on the fairness of the remuneration. The main aspect for future is to define groups of consumers in a way that the consumers understand how the groups were created, i.e. why one consumer has been activated and another one with similar characteristics has not been activated.

DR for network operation issues: what challenges?

The activation and design of DR programs can be driven to economic and technical reasons. In one side, Dr can be activated when there is a high market price for electricity. In the other side, some consumption can be deactivated so solve a voltage issue or congestion in the grid. In fact, in the second case, it requires the interaction between DSO and aggregators has most of the times the DSO as not direct contractual relation with consumers in order to contact, activate, and remunerate them for the participation in DR event. This rises the discussion about who as right to access which information in the operation of the grid and of the market.

How many different contexts can be defined?

In the COLORS project, contextual approaches have been defined to address several aspects of DR programs. In fact, it has been concluded that the contextual approach to each aspect is effective. However, there is not a general way to define the number of contexts to be implemented in each aspect to be dealt with. Therefore, as additional features appear in each problem, those can be seen as features to define new or additional contexts.

Many other questions can be derived from these ones with the target of releasing the full potential of DR, without loss of comfort from electricity consumers.

COLORS list of publications

This section presents the list of publications of COLORS project, for further reading.

Journals

Silva, C., Faria, P., Fernandes, A.,and Vale, Z., "Clustering distributed Energy Storage units for the aggregation of optimized local solar energy," Energy Reports, vol. 8, pp. 405–410, Jun. 2022. doi.org/10.1016/j.egyr.2022.01.043

Faria P., and Vale, Z., "Application of distinct demand response program during the ramping and sustained response period," Energy Reports, vol. 8, pp. 411–416, Jun. 2022. doi.org/10.1016/j.egyr.2022.01.044

Faria, P., Lezama, F., Vale, Z., and Khorram, M., "A methodology for energy key performance indicators analysis". Energy Informatics 4, 6, Apr. 2021. https://doi.org/10.1186/s42162-021-00140-0

Faria, P., and Vale, Z., "Distributed Energy Resources Scheduling with Demand Response Complex Contract," Journal of Modern Power Systems and Clean Energy, Page(s): 1 – 13, 10 December 2020. doi.org/35833/MPCE.2020.000317

Faria, P., Corsi, P., and Vale, Z., "Online Estimation and Use of Price Elasticity of Demand for Shifting Loads Through Real-Time Pricing," Energy Reports, Volume 6, Supplement 8, pp. 93-98, December 2020. doi.org/1016/j.egyr.2020.12.017

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