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Transition to Future Power Systems in the SEERC Region

Towards Resilient hybrid Medium and Low Voltage AC-DC Power Grids – A European Perspective

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SUMMARY

Resilient hybrid Alternating Current (AC)-Direct Current (DC) power grids are discussed as a potential future solution for distribution power grid flexibilization to enable connecting a high-share of renewable sources (photovoltaic, wind), new DC-based loads (electric vehicles, heat-humps), and storages instead of cost and carbon emissions-intensive AC standard grid solutions (new cables and power transformers) for grid reinforcement when existing grid parts come to their capacity and power quality limits and also for new installations. This work identifies main drivers and technology requirements, important use-cases, standardization, regulatory, and market needs. It introduces as examples the actual running European demonstration projects HYPER-RIDE and TIGON funded by the European Commission and highlights their common positioning and future activities/developments on the topic of hybrid AC-DC power grids based on their description of work and the findings of other international DC-grid initiatives like actual published CIRED WG-2019-1 “DC distribution networks” report and CIRED 2021 Round Table “DC networks” results which are also summarized.

KEYWORDS

AC-DC Grid, DC Technology, Power System Control, Use Cases, Requirements, Market Needs.

1 Introduction

In the 2015 Paris Agreement, the global community pledged to limit global warming to well below two degrees Celsius and, if possible, to below 1.5 degrees Celsius compared to the pre-industrial level. In December 2019, European Union (EU) leaders committed to the goal of climate neutrality by 2050 and following measures ("Green Deal"). In December 2020, EU leaders agreed to raise the EU's 2030 climate target from the current minimum of 40 to at least 55 percent below 1990 levels. Accordingly, the EU's internal greenhouse gas emissions are to be reduced by at least 55 percent by 2030 compared to 1990. In parallel, from the International Energy Agency (IEA), scenarios of global growing demand for electrical energy as much as 50% until 2040 were developed based on experts' estimates because around 650 million people worldwide still have no access to electricity [1],[2].

As consequence, since the last decade, the energy supply business in Europe faces enormous changes never seen before as the center of this transformation. The above-mentioned climate goals will strongly and sustainably influence the energy market especially in Europe, but also abroad during the actual and next decades. In the last years, power grids were at the center of the integration of decentralized generation with renewable energy sources (wind, photovoltaic, biomass). Recently, also sector coupling concepts like Power-to-Gas, Power-to-Heat, Hybrid Power Plants, the electrification of the industrial processes, and integration of electric vehicles and storage units gain importance to reach the ambitious climate goals [3]-[8].

When someone looks at power grids and their transition to smart grids, a growing number of sources and consumers of electricity are natively producing or using Direct Current (DC), for example, Renewable Energy Sources (RES) such as Photovoltaics (PV) and speed-controlled wind turbines, e-mobility solutions, storage units, and a majority of new electric appliances from domestic to industrial sectors. At the same time, a lot of progress is reported in terms of high-power electronic components (incl. new wide-bandgap developments with SiC and GaN), adapted DC breakers, and solid-state transformers. This paves the way for DC network demonstration projects and raises the question of the place these technological solutions may have in the future taking into account also the steady decrease of market prices for high-power power-electronics converter products.

This work, therefore, identifies main drivers and technology requirements, important use-cases, standardization, regulatory, and market needs. It introduces as examples the actual running European demonstration projects HYPERRIDE and TIGON funded by the European Commission and highlights their common positioning and future activities/developments on the topic of hybrid AC-DC power grids based on their description of work and the findings of other international DC-grid initiatives

This paper is organized as follows: Section 2 outlines the path towards DC-enabled power systems whereas Section 3 introduces two examples of European DC technology development projects. Necessary future activities and developments are discussed in Section 4 followed by the conclusions in Section 5.

2 Towards DC-enabled Power Systems

2.1 Main Drivers and Technology Needs

“DC networks on distribution level – are they a new trend or a vision?” That is the question that has focused the efforts of the CIRED Working Group 2019-1 “DC distribution networks” with a recent report [3], and whose consideration is in the following summarized. This report represents the first phase evaluation of this topic and is focused primarily on medium (MVDC) and low voltage (LVDC) level applications including the results of international surveys from universities, Research and Technology Organizations (RTO), manufacturers, and utility areas.

Distribution System Operators (DSO) are faced with ever-increasing claims for cost efficiency and supply quality requirements. Further, new challenges are emerging, such as supplying charging stations for Electric Vehicles (EV), the integration of distributed power generation and storage, as well as support for demand response. Therefore, a more flexible distribution grid with higher controllability helps to meet the requirements.

DC can improve the grid operation in terms of providing reactive and active power capacity and, voltage controllability. DC solutions can also be economical compared to the AC alternatives in some cases (e.g., a new power transformer or cable). In addition, DC solutions are already established in specific applications like point-to-point High Voltage DC (HVDC) transmission systems, DC grids for public transport like city tram or subway, ships, and airplane board grids, data centers, Uninterruptable Power Supplies (UPS), and many more [3]-[8].

As the majority of new energy applications including renewables, e-mobility, or storage are internally DC-based, the prospect of DC or hybrid AC/DC distribution offers connections through DC-DC converters that are more efficient and architecturally simpler. In this sense, they are more than just a vision. Although any deployment of DC distribution grids on a large scale remains unproven given some missing key technologies remain in development, several of their outstanding high-level benefits have been identified and demonstrated, including the following [3]:

- Expanding the capacity of power lines and grids to host greater volumes of renewables distributed energy resources, e-mobility, and other DC-based loads;
- Increased energy supply radius and decreased concerns for power quality;
- Improving the system energy and resources efficiency;
- Enhanced grid resilience and management in case of grid faults; and
- More environmentally friendly and sustainable use of resources in production and operation.

Over the last decade, several early technologies for the realization of DC distribution have been demonstrated in a variety of pilot installations and research platforms across several countries. The lessons learned from these early pilots evidence the effective contribution that DC distribution networks can make to grid optimization and stabilization, laying foundations for a net zero-carbon energy future. The potential for lowering the cost of the energy transition exists. Therefore, it is entirely feasible for AC and DC grids to coexist within hybrid AC/DC energy systems for future power distribution, both, behind (prosumer) and in front of (utility, energy communities) the meter.

Despite all the development and euphoria around the DC distribution networks, the majority of technical solutions and devices remain in the pilot project stage and key standards and as consequence, the commercial markets are missing. To determine the extent to which and if a large-scale breakthrough of this relatively new technology is reasonable for which distribution grid use-cases, areas (utility, industrial, or building/infrastructure) and on which voltage level (low and medium voltages) the following actions and additional investments in this field will be required:

Essential research questions have to be answered and key technologies as well as techno-economic planning tools to be developed by universities, RTOs in collaboration with Original Equipment Manufacturers (OEM);

- Clear use-cases, exploitation strategies and business models for their products and services have to be formulated by RTOs, OEMs, and service providers;
- International standards and regulations have to be defined by standardization bodies and regulatory authorities;
- Answers to the long-term impact of DC integration into the public Medium Voltage (MV) and Low Voltage (LV) networks (in terms of capacity and ease to connect future customers in the surroundings of a DC investment, or capacity to reconfigure the grids at least the same way it is done in AC); and
- Operational safety and experience have to be gained for these systems by DSOs in more pilot projects on a short and mid-term perspective to keep a safe, reliable, and trustful future supply system.

In this context also the work of CIGRE WG C6.31 with its “Medium voltage direct current (MVDC) grid feasibility study” reported in Technical Brochure 793 (2020) [4] dealing with similar issues focused on MVDC grids and aims comparable actions as mentioned for CIRED WG 2019-1 above.

2.2 Important Use-Cases

The CIRED WG-2019-1 report on “DC distribution networks” [3] reports on 14 worldwide realized pilot installations with MVDC and LVDC grid-related use-cases and in addition potential (future) DC grid use-cases are summarized. The centers of the developments were mainly Europe, East Asia, and North America. Also, lessons learned from these projects were reported, if available.

One example is the following demonstration project from the Netherlands. The provincial road N470 was a one-of-a-kind project for a region, involving multiple partners. South Holland aspires to manage and maintain its roads, waterways, bridges, and locks in a carbon-neutral manner [9]. These spectacular goals have been realized in the N470 project by creating the most sustainable road in the Netherlands, and by demonstrating to the market that this is a normal tender, not a demonstration project within the existing ecosystem.

It is the first road in the region to have been renovated entirely in a CO_2-negative manner and to generate its energy for lighting and traffic signals. Additionally, traffic can continue to flow more freely, and the road has been made safer through the use of new DC technologies. The distances are short, which prevents electricity from being lost during transmission via high-voltage cables and conversion to AC. This minimizes energy consumption and CO_2 emissions. The green battery stores the energy generated during the day so that it can be used later in the evening when the sun is not shining.

The N470 is the first to be equipped with a self-sufficient energy system. The Energy Wall is a noise barrier that also produces energy via solar panels embedded in the screen's glass plates. The generated energy can be used directly to power 332 lights and 225 traffic lights further down the road. The noise barrier is made up of 100 kW solar and generates 75 megawatt-hours of electricity per year. This is approximately the same as providing green electricity to approximately 26 households for one year.

From the recent CIRED 2021 Round Table “DC networks” [10] following aspects were concluded: Main drivers are PV and EV integration, as well as big data centers. The applications that appear as targets are DC-microgrids, hybrid ACDC grids (last mile LVDC, then MVDC), DC within buildings, factories, and high-power EV charging. Needs for commercial availability of DC system integration products (protection, control, and grounding) and better coordination/knowledge sharing across research projects were highlighted. In short: “DC is on the way”, starting with gathering the operating experience of LVDC distribution networks and behind the meter, then low MVDC levels up to several kilo Volt.

2.3 Standardization, Market, and Regulatory Needs

In the CIRED 2021 Round Table “DC networks” [10] international experts in the field estimate that needed key standards for MVDC and LVDC distribution levels up to several kilo Volt will be developed in the upcoming 3-5 years to extend the limited standards for existing single, separate or isolated from the AC-main grid operated niche applications like telecom and data and traction, ships, aircraft applications, etc. Therefore, they see now it’s time for manufacturers' participation and tries to find here a wide agreement on essential standards and to avoid the same mistakes which were historically made with AC standards (e.g. the spread of different nominal voltage levels all over the world). As an example the work of IEC TC8 WG9 with technical report IEC TR 63282:2020 can be mentioned, dealing with standard voltage assessment and power quality requirements for LVDC distribution based on semiconductor-based grid technologies (power converters) [11]. Then respective markets will most probably follow based on appropriate use and business cases demonstrated.

Another important issue is to collect operational experience from demonstrating use-cases in pilot projects. Concerning regulations, the experts argue a chicken-egg problem. Because most of the European regulators and DSOs ask for existing standards - which are at the moment not in place – before they support DC distribution grid pilot projects in their public grids based on new power semiconductors-based hybrid and solid-state technology developments; quite understandable mainly because of security reasons. There are some exceptions like in the Netherlands where there is an acceptance for these first public LVDC grid pilots on the principle “to implement the highest level of security possible” based on agreed Dutch technical guidelines for DC installations (NPR9090) to collect the needed operational experience in the field (refer to the “green” N470 project in Section 2.2 and other already realized) and prepare pre-standards based on demonstrated control and protection protocols like CurrentOS [12] with the help of technology providers. The corresponding CurrentOS foundation including the manufacturers Schneider Electric, Eaton, and others could be a good approach to gather an open protocol to become an international standard.

Alternatively, in Finland LVDC demonstration pilots in utility are based on commercially available electromechanical protection equipment and concepts resulting in some oversizing of converters to supply residential AC customers via AC/DC back conversion [3]. The final responsibility takes in both cases the local DSO for operating these hybrid AC-DC architectures. Other countries and DSOs in Europe are more restrictive and only support if at all DC grid pilots with grid connection/Point-of-Common-Coupling (PCC) behind the AC meter on customer (AC/DC conversion) and operated separated (with galvanic isolation) from the AC main grid.

3 Examples of European DC Technology Development Projects

3.1 H2020 HYPERRIDE

The HYPERRIDE[1] project addresses the field implementation of DC and hybrid AC/DC grids (see Figure 3-1). Grid planning and operation guidelines are developed and available sizing tools are adapted for DC. Technology Readiness Level (TRL) of enabling technologies will be raised focused on MVDC breakers, sensors, and DC measurement units to provide field-ready devices for grid automation and protection. Automation algorithms are created, validated, and transferred to demo sites. This involves concepts and solutions for cyber security and fault mitigation to avoid cascading effects.

Demonstrations in Aachen (DE), Lausanne (CH), Terni (IT) will showcase the above mentioned technologies. The benefits of the solutions are evaluated, especially the integration potential of renewables. Business models are created for products, services, and applications.

3.1.1 Overview

With increasing contributions from internal direct current (DC) based renewable energy sources, electromobility and battery storages, low-voltage DC grids or DC coupled with AC in a hybrid network could enable more stable, efficient, and sustainable electricity distribution at lower costs. The proposed solutions in HYPERRIDE will contribute to

- Facilitating planning and targeting investments in the sector;
- Increasing resilience of the electricity grid to faults and cyberattacks;
- Increasing penetration of renewable energy resources (RES) in the power network;
- Increasing the efficiency of the electricity system (system level).

The HYPERRIDE project is developing the technologies to make this possible with planned demonstrations in a variety of use cases. All this will be accompanied by business models for the resulting products, services, and applications:

- *Replicability:* Modular, techno-economic DSO grid planning approach for the transition of AC to AC/DC hybrid grids including a component sizing tool. Interoperable, open Information and Communication Technology (ICT) platform, data models for interoperability, and open reliability information database. Configurable MVDC and LVDC components model library for controls, protection, stability assessment considering several use-cases.
- *Environment:* Enhancing energy efficiency on the system level as well as application side and sustainable resource usage (CO_2 footprint). DC-Grids enable the connection of a higher share of renewables (PV, wind) and DC-based loads (EVs, heat pumps/cooling systems) to the grid.

[1] https://hyperride.eu

From 2020 to 2024	Project total cost	EU contribution	Website
	8.2 M€	7.0 M€	www.hyperride.eu

Technologies and services deployed

Technologies for consumers	---
Grid technologies	✓MVDC, MVDC circuit breakers ✓Protections ✓Network management, monitoring and control tools ✓Micro-grid ✓Multi-terminal
Large-scale storage technologies	---
Distributed storage technologies	✓Batteries, Electric Vehicles
Generation technologies	✓ PV
Market	✓Electricity market ✓Ancillary services

Consortium Countries

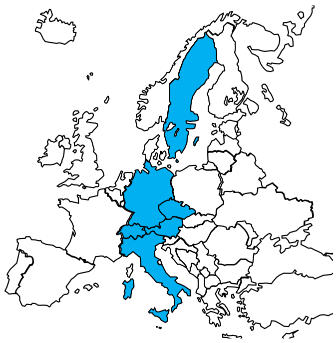

Figure 3-1: Overview of the HYPERRIDE targets.

- *Market Transformation:* Steadily falling prices of semiconductor-based devices and wide bandgap components enable new DC use-cases. A cost-benefit analysis (CBA) is carried out for the most promising use-cases, development of business models for the deployment of new services. Activities are aligned with other developments to increase the replication potential of the developed solutions for smart grids and energy storage applications (e.g., local energy communities).
- *Policy:* Enhancing energy efficiency and sustainability is a key pillar of most policy initiatives. HYPERRIDE will contribute to the H2020 BRIDGE initiative across projects and in addition organize best practice exchanges and methodology workshops at demonstration sites where use-cases are discussed with local industrial-style stakeholders. Comparative analysis of legal and regulatory framework (hybrid AC/DC grids) in the countries of the demo sites including policy recommendations (analysis of barriers for promising use-cases).

3.1.2 Planned Developments

The main objective is to demonstrate MVDC/LVDC AC/DC hybrid grid architectures based on a DC underlay grid interconnecting micro/nano-grids on target TRL 5-8. This includes the following further objectives:

- Planning, operation, and automation solutions, incl. operation on and separated from the main AC grid;
- Development of enabling technologies like MVDC circuit breakers and sensors, DC measurement unit, open interoperable ICT platform, open reliability database, test and validation services;
- Fault management and cybersecurity solutions, incl. protection coordination, stability assessment, and automatic grid reconfiguration;
- Technology demonstrations in three countries by virtually linked demo-sites;
- Effective business models & knowledge transfer, recommendations for standardization, and regulatory bodies.

3.1.3 Demos

The following three demonstrations are planned:

- *Demo 1 (Lausanne, CH) – LVDC AC/DC hybrid campus grids (see Figure 3-2):* LV Hybrid AC/DC microgrid with a foreseen connection of 400Vac, 50Hz; CIGRE 15 nodes benchmark grid DES Lab and MV LVDC PE Lab via 4 LVDC lines 700-750V and Active ACDC Frontend converters. 4 busses DC network with DCDC converters a bus-tie switch and a supercapacitor (further DC applications under investigation); installed LVAC applications are PV, BESS, EV-charging, fuel cell, supercapacitor, electrolyzer, hydro oxygen storage, heat pump; planned technologies and services are in HYPERRIDE developed DC measurement units integration and investigation optimal control, adaptive feeder reconfiguration, protection coordination, and stability assessment.
- *Demo 2 (Aachen, DE) – MV/LV DC AC/DC hybrid campus grids (see Figure 3-3):* Existing and in Europe unique MVDC infrastructure with installed 5 kV(±2,5 kV) MV LVDC converters in Megawatt range, 5 km MVDC cables, wind power test bench (4 MW turbine), Active ACDC front end converter. Potentially LV applications are PV, BESS, and fast EV-charging stations (380-1000 VDC), planned technologies and services are the integration of in HYPERRIDE developed MVDC circuit breakers/sensors and DC measurement units and investigating optimal power flow as well as fault detection and location services.

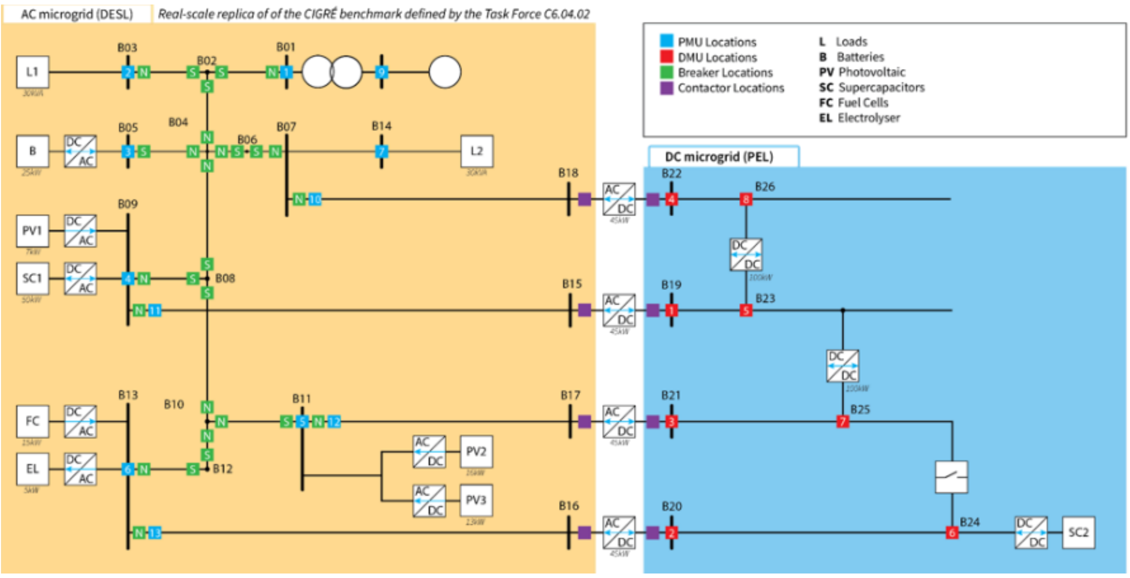

Figure 3-2: HYPERRIDE Demo1 in Switzerland, EPFL hybrid LV AC/DC campus microgrid.

- *Demo 3 (Terni, Italy) – LV AC/DC hybrid DSO grids with connection to MVAC grid via AC-transformer in the field (see Figure 3-4):* Setup of an LV AC/DC hybrid grid in a “living” DSO grid with connection via MV LVAC-transformers. It extends a section of the AC grid, which already consists of RES, industrial and residential customers by a DC grid part. Hybrid AC/DC microgrid includes battery energy storage, PV array, Vehicle-to-Grid (V2G) EV fast-charging station, and office loads. Active ACDC Front End Converters and commercially available DCDC converters are to be implemented together with suitable automation algorithms and protection equipment for microgrid operation on-grid and islanded from the main grid.

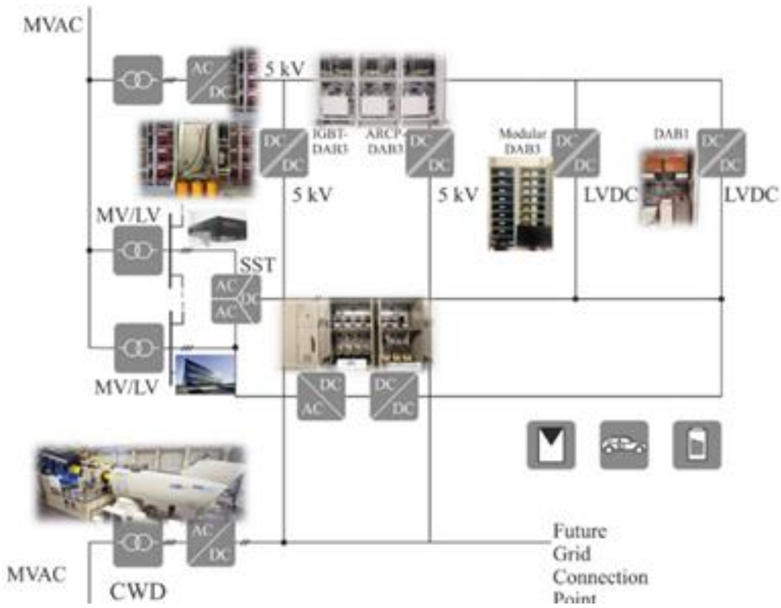

Figure 3-3: HYPERRIDE Demo2 in Germany, RWTH Aachen MV/LV DC Campus grid.

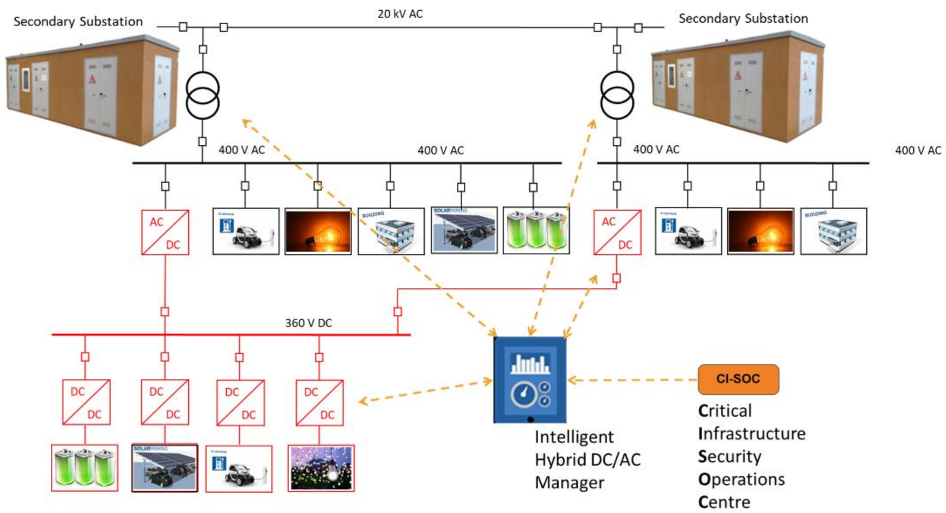

Figure 3-4: HYPERRIDE Demo3 in Italy, ASM Terni hybrid LV AC/DC DSO grid in the field.

3.2 H2020 TIGON

3.2.1 Overview

The TIGON[2] project has been designed to cope with this need by demonstrating innovative DC technologies in two DC-based hybrid grids to improve their reliability, resilience, and performance in a smart and cost-efficient way. To do so, a modular concept of DC-based grid topology is proposed consisting of an MVDC line connecting the main grid with the LV hybrid grid. Based on this concept, TIGON demonstrators will integrate in a more efficient way distributed RES, energy storage, and a variety of loads including electric vehicles. At the same time, the MVDC line will be exploited by integrating a higher amount of RES and providing ancillary services through energy storage systems and their related operation modes and control strategies.

[2] https://tigon-project.eu/

Under this context, TIGON aims to achieve a smooth deployment and integration of intelligent DC-based grid architectures within the current energy system while providing ancillary services to the main network. To do so, TIGON proposes a four-level approach aiming at improving (i) reliability, (ii) resilience, (iii) performance, and (iv) cost efficiency of hybrid grids through the development of an innovative portfolio of power electronic solutions and software systems and tools focused on the efficient monitoring, control, and management of DC grids. These solutions will be demonstrated in two main demo-sites located in France and Spain, while additional use-cases in the residential and urban railway sectors will act as niche markets for analyzing and further solidifying the replication of TIGON developments after the project's end.

3.2.2 Planned Developments

TIGON has been conceived to design, model, and develop innovative DC-based grid architectures to improve the reliability, resilience, and performance of hybrid grids smartly and cost-effectively. To do so, TIGON will develop a set of flexible and highly replicable hardware and software solutions that will optimize the control, operation, and protection of DC grids, while providing ancillary services to both the main network and the end-users connected to the hybrid energy system. To this end, a modular concept of DC-based hybrid grid is proposed as depicted in Figure 3-5, in which the main connection of the MVDC to the grid is performed by a Solid-State Transformer (SST) and different assets and LV grids depart at several points of the microgrid in an interconnected manner.

The implementation of the SST will be complemented by the installation across the hybrid micro-grid of novel topologies of high-efficiency DC/DC converters, enabling the grid to distribute energy at several voltage levels while increasing the efficiency and power density of the power conversion stages. To this end, recent developments in SiC power semiconductor technology will be applied to aim at demonstrating its improved performance when compared to conventional-based power electronics, thus contributing to its market uptake and consequently its future cost reduction linked to higher demand. Horizontal to these developments, novel protection schemes for DC and a Wide Area of Monitoring, Protection, and Control (WAMPAC) system will be developed and demonstrated to assure the stability and security of hybrid grids. The WAMPAC system will allow the monitoring of the AC/DC connection points, thus providing the status of the grid in real-time, and will send control instructions to the active assets of the grid depending on its status, including the disconnection of elements facing anomalous situations in the grid to protect it.

To ensure a secure and optimized management of electricity generation and consumption in these grids given the variety of technologies taking part in their daily operation, TIGON includes the development of a smart Energy Management System (EMS) able to control in a centralized manner each one of the micro-grids under analysis, while taking advantage of the improved smartness of the new converters. In this regard, fault tolerance will be enhanced, since asset agents would be able to take control in case of a failure at the Micro-Grid Centralized Controller (MGCC) or the main communication link. Moreover, DC-enabled intelligent devices will facilitate demand response capability, adding flexibility and reducing computational effort and costs at the MGCC side, and will enable fast swapping between master/slave control modes based on the different operation scenarios and voltage/frequency needs at stake.

The required communications together with the digitalization of the grid and the improved smartness of the grid make it mandatory for TIGON to take also into account cybersecurity issues. To this end, a Cybersecurity defense system will be developed by adhering to the latest Commission recommendations on cybersecurity in the energy sector. As a result, TIGON will count on a fast, distributed security framework that intelligently incorporates the physical state of the defended system and blocks incorrect operation actions.

All these innovations together with the operation modes, grid configurations, and final recommendations of TIGON will be gathered into a Decision Support System (DSS) that will provide guidelines facilitating the planning of grid expansions or the development of new hybrid grids across the EU. Another feature of the DSS will be to develop strategies enabling a fast and optimal restoration of operation in the case of faults or emergencies.

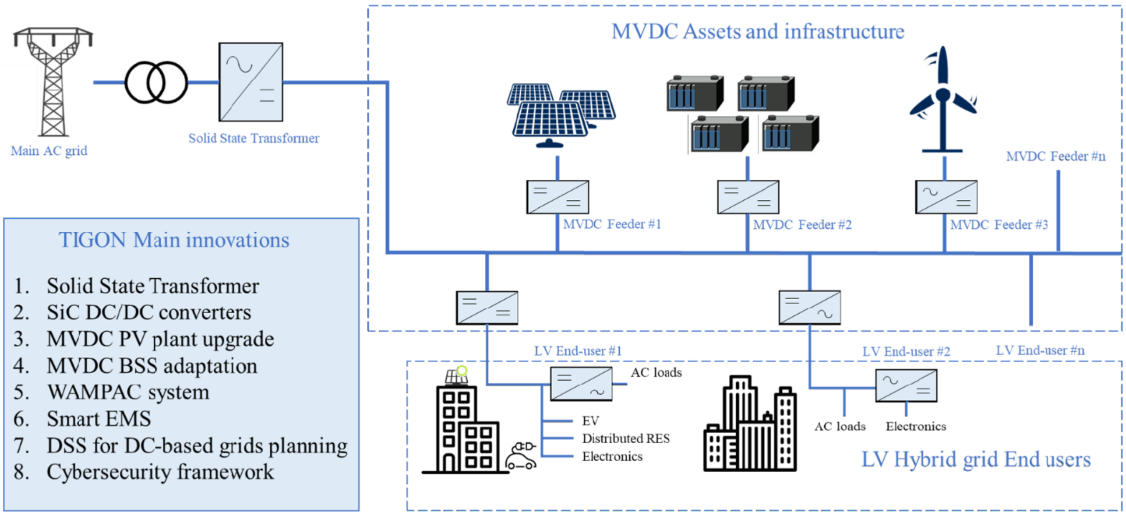

Figure 3-5: TIGON's main concept and innovations are listed and represented in the AC/DC hybrid grid example.

3.2.3 Demos

To be able to validate the performance of the solutions developed within TIGON under alternative scenarios, they will be tested in two different demo sites located in France and Spain. Although both pilots will test the main concept of the TIGON modular DC-based grid, the particularities and specific requirements of each demo site will imply alternative approaches for the optimization of the overall network.

In line with the information collected during the demonstration activities, the next phase of TIGON will deal with the final validation of the technologies under demonstration and the development of the replication strategy in systems with different contexts and power scales. To this end, a follow-up of the real performance of the demo-sites before the generation and transfer of main conclusions will be used to fine-tune the solutions when needed and start defining their future potential.

Regarding replication, according to transition theory and examples from other sustainability projects, it is most likely that DC application will initially enter niche markets and/or protective technological niches before penetrating the mainstream market. This is also because these markets that exhibit DC-based systems are already existing. On one hand, within TIGON the niche market of electromobility has been selected, in particular, the urban railway sector focusing on the application example of Sofia, Bulgaria. The main reason is that urban railways provide a main DC-network transversal to the whole city and therefore are ideal for interacting with the main AC distribution grid of the city and supporting the expansion of the DC grid to supply new EV charging infrastructure or distributed RES under installation now in most of EU cities. On the other hand, sustainable local energy production and storage with DC microgrid study is carried out at Naantali, Finland. New control and protection strategies will be analyzed to optimize the management of renewable energy production as well as the use of the storage systems, thus improving the overall efficiency of the smart DC microgrid. A particular emphasis will be placed on the correct management of the bi-directional energy flows due to the inclusion of RES in the grid.

A summary of each site's characteristics and improvements is provided in Figure 3-6.

	Demo-site INES-CEA (France)	Demo-site CIEMAT (Spain)	Use-case Naantali (Finland)	Use-case Sofia (Bulgaria)
				
Specific location	Le Bourget-du-Lac	Soria	Lunnonmaa Res.Dist.	Metro Network
Type of network	MV DC	MV-LV DC	LV DC Res. Microgrid	MV-LV AC
Deployment and set-up	12.2021 – 11.2022	12.2021 – 11.2022	03.2023 - 08.2024(?)	03.2023 - 08.2024(?)
Operation, evaluation and impact assessment	11.2022 – 08.2024	11.2022 – 08.2024	09.2023 - 08.2024	09.2023 - 08.2024
Keywords	#PV Plant	#Battery Storage System, #RES connection	#Energy Management System, #Solar&Storage	#DSO Network, #Resilience
Main study	Improve CAPEX of PV Plants (cost reduction + efficiency)	Better Connected RES reability, stability and security supply	Optimized RES Produced Management + Improve Smart DC microgrid efficiency	Enhance the stability of the DSO network + Efficient operation of DC and AC grids
Side outputs expected	SiC WBG MV DC/DC converters – Dedicated DCMV Protections	Including a BSS plant connected to the MVDC grid, providing flexibility	Integrate Photovoltaic Power Plant and Energy Storage System	Resilient network (e.g: breakdowns, interconnection in parkings..)

Figure 3-6: Overview of TIGON demo-sites (France and Spain) and use-cases (Finland and Bulgaria).

4 Future Activities and Developments

Another key element for successful hybrid ACDC grid developments is better coordination/knowledge sharing across research projects as well as common activities and positioning (messages).

The major common goal of HYPERRIDE and TIGON characterized by their Innovation Actions with planned technology demonstrations is to enable a hybrid ACDC grid integration in European distribution power grids to support the decarbonization of the energy sector. TIGON project has here a focus on MVDC grid technology developments and use-cases (DC/DC converters, solid-state transformers) for utility applications, whereas HYPERRIDE besides utilizing Aachen MVDC campus grid infrastructure is also focused on LVDC microgrid developments in nationhood to other customers (ASM Terni demonstration). Both projects aim to foster hybrid ACDC grid integration technologies like controls and ICT, DC protection, system grounding, sensors, and measuring and interoperability issues to integrate a high share of RES (PV, Wind), new DC loads (e.g., EVs), and storages for grid flexibilization. Efficiency considerations are evaluated on the system level. Cost-effective solutions and business models for potential use-cases shall be investigated and exploitation strategies for the developed technologies to be derived. New active power converter-based hybrid ACDC grid architectures shall lead to more stable, resilient, and reliable power distribution grids in case of outages of the AC main grid or to avoid cascade effects, including grid reconfiguration strategies and an independent operation mode from the AC main grid with grid forming microgrid capabilities. Possible use-cases are e.g. future energy communities and resilient networks after natural disasters or major transmission system blackouts with black-start support to locally build up the AC main grid.

Target groups of HYPRRIDE and TIGON are the following stakeholders and common audience: DSOs, manufacturers/industry, public infrastructure operators, regulators/standardization bodies, as well as technology and service providers. Consumers and the wider public are planned to include in a second step (follow-up projects).

Therefore, the following future activities are planned between projects HYPERRIDE and TIGON based on the results of the first virtual meetings:

- Regular virtual meetings for knowledge exchange and to lift synergies (including H2020 BRIDGE activities) and common strategy developments;
- Dissemination of results in open-access platforms like Zenodo, OpenAIRE, etc.;
- Common physical workshops with involvement of relevant stakeholders at demonstration sites (consortium partners) or conferences/workshops (if possible from COVID-19 situation);
- Make use of communication channels from EC and the projects (home page and in social media channels) to inform about activities of the H2020 sister project;
- Common publications and positioning papers like actual one (CIGRE, CIRED, IEEE, international journals, etc.);
- Participation in corresponding CIGRE- and CIRED Working-Groups and involving standardization bodies/members in the projects (e.g. From IEC TC8 WG9);
- Contribute to national and European Smart Grid regulators activities (at least on an informal basis); and
- Look for complimentary funds or common topics.

5 Conclusion

Hybrid ACDC distribution power grids based on active power electronics technologies provide some superior advantages for grid flexibilization like a high capacity enhancement of power cables and lines and reduction of power quality issues in comparison to standard AC grid solutions for the transition of the energy sector towards resilient, cost and energy-efficient, decarbonized power grids. This paper summarizes DC technologies and potential future use-cases based on CIRED WG 2019-1 “DC distribution networks” report and CIRED 2021 Round Table “DC networks” results. The main drivers are EV and PV integration, also big data centers. Resumé: “DC is on the way”, by starting to gather LVDC distribution networks operational experience and behind the meter, then low MVDC levels up to several Kilovolts (lower TRLs). Now it’s time for manufacturers' participation in resolving key standards for the upcoming 3-5 years! Target applications are DC-microgrids, hybrid ACDC grids (last mile LVDC, then MVDC), DC within buildings, factories, and for high-power EV charging (till around 1 Megawatt large vehicles). There are needs for commercial availability of DC system integration products (protection, control, and grounding) and better coordination/knowledge sharing across research projects.

As examples for common activities and positioning the running European projects HYPERRIDE and TIGON were introduced. Their Innovation Actions with planned technology demonstrations aim to enable hybrid ACDC grid integration in European distribution power grids to support the decarbonization goals. Similar and complementary topics on technology developments were identified. Target groups are DSOs, manufacturers/industry, public infrastructure operators, regulators/standardization bodies, as well as technology and service providers. Several future common activities were defined for knowledge transfer between these sister projects, to reach and involve the different stakeholders, dissemination of project results, and to look for complimentary funds or common topics.

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