PAPER

MVDC and Grid Interties: enabling new features in distribution, sub-transmission and industrial networks

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MVDC and Grid Interties applications overview

Medium voltage direct current (MVDC) applications in distribution grids are nowadays becoming reality in the first pioneering demonstration projects. [1]

As an example, Network Equilibrium project in UK represents the first case where an MVDC converter has been installed in a distribution network. This pilot application consists in connecting two adjacent distribution grids by a back-to-back (B2B) converter between South West England and Wales [2].

In addition to MVDC applications related to distribution or sub-transmission networks, academic discussions are ongoing about the use of MVDC for the integration to the electrical grid of distributed energy resources (DER) or loads which utilize DC voltage rather than AC voltages.

Similarly, transportation systems and data centers are examples of DC based loads. The conversion to and from AC voltage requires an additional step that can be avoided if DC distribution systems are deployed, resulting in reduced conversion losses.

The integration of DC loads (fast charging stations for electric vehicles, data centers), DC generation plants (wind and mainly solar) and battery energy systems by means of DC/DC converters is expected to be a major driver for the introduction of MVDC. The main reason is that in this case conversion cost (CAPEX and OPEX) can be reduced significantly.

In addition to what above, industrial grid interties are common practice whenever a production facility shall be connected to the local grid with different frequencies (50 to 60 Hz and vice versa).

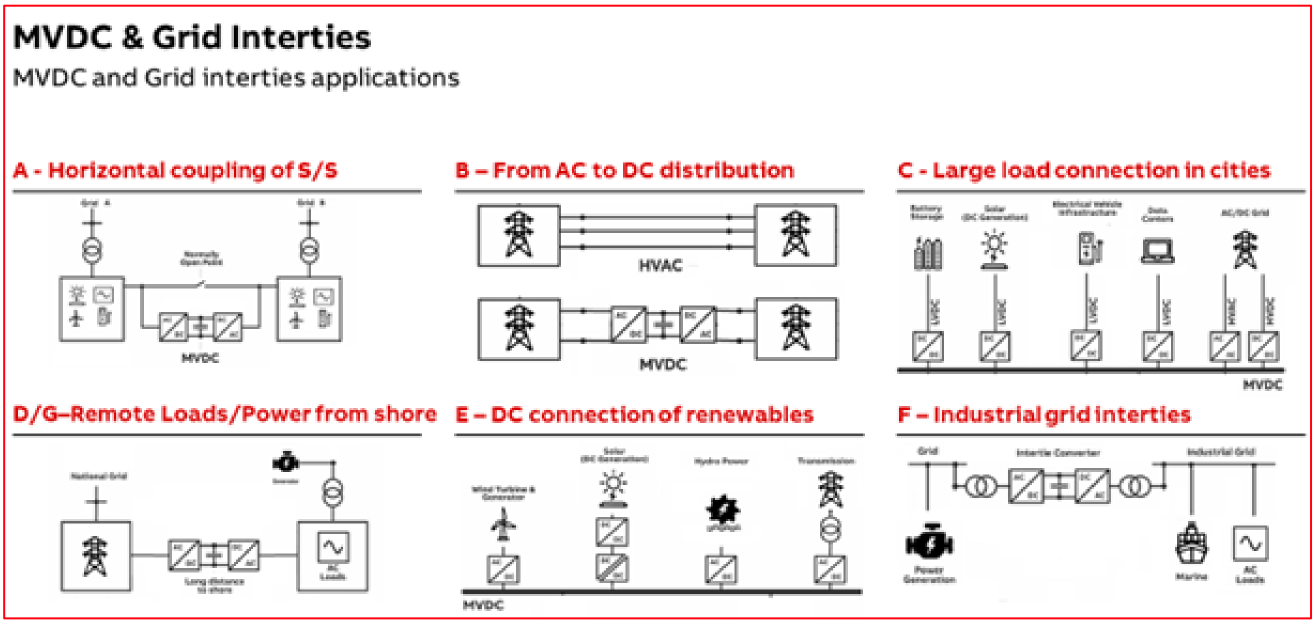

Figure 1 – MVDC and Grid Interties applications

Application A - Horizontal coupling of substation

On distribution or sub-transmission grid level, there are often grid sections that cannot be interconnected right away, due to:

- Phase angle differences
- Frequency differences of the two connection systems
- Excessive harmonics or flicker in one grid section
- Short-circuit current would otherwise be exceeded
- Redundant parallel supply from another utility/distribution grid to a same island grid
- Different concept of neutral earthing of each network

However, for several reasons it would be beneficial to interconnect such grids despite of the above limitations:

- Overcome capacity limits in grid sections, due e.g. growing distributed generation / Provide capacity enhancement
- Power flow shall be controlled
- Voltage or reactive power shall be controlled dynamically on either connected AC grid
- De-coupling one AC grid from the other due to power quality or short circuit capacity reasons.

This application is sometimes also referred to “Soft Open Point (SOP)”

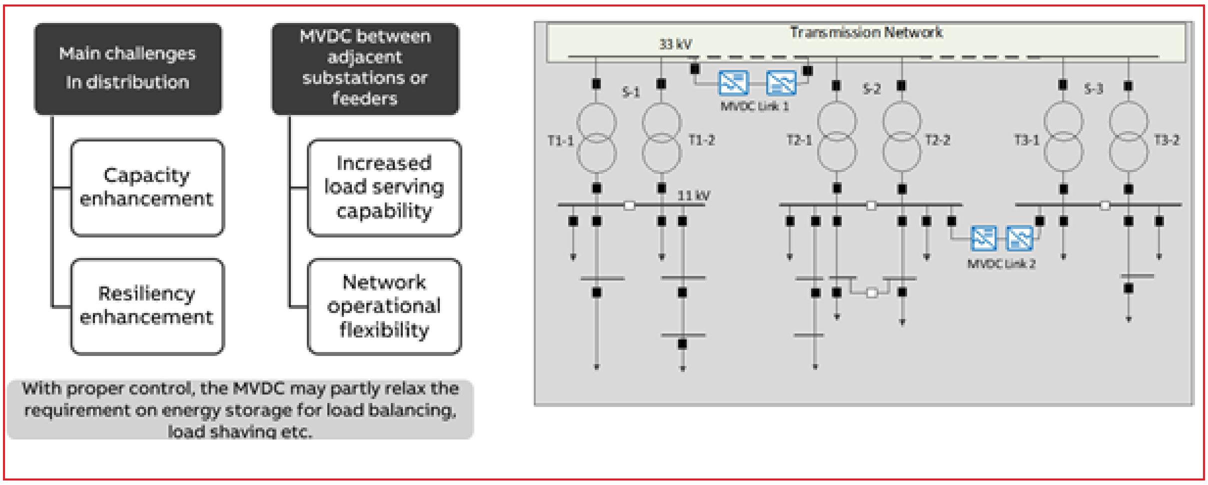

Figure 2 – Horizontal coupling of substations

The existing 20 MVA flexible power link installation in UK represents a milestone in horizontal coupling of substations. [2]

An additional application would be the establishment of merchant distribution or sub-transmission lines, representing an arrangement where a third-party construct and operates electric lines through the franchise area of an unrelated incumbent utility.

Application B – Converting AC distribution to DC distribution

Converting existing lines from AC to DC can significantly increase the power capacity of an existing grid. For long, congested feeders in meshed distribution grids, line conversion can be a cost-efficient solution for increasing the power rating [3]. In addition to this greater power transfer, it is possible to improve grid stability providing embedded STATCOM functionalities on both sides of the grid.

Key customer benefits are:

- Avoid network expansions, while re-using existing AC lines
- Limit the environmental impact with installation of new DC cable instead than traditional AC overhead lines
- Increased asset utilization with 20-80 percent more transmitted power
- Grid stabilization

The limit of such application is determined by the length of the connection, as the cable losses can become significant.

Application C – Large load connections in cities

Adding new transmission capacity by AC lines into city centers is costly and in many cases the permits for new right of ways are difficult to get. A DC cable needs less space than an AC overhead line and can carry more power than an AC cable and is therefore many times the only practical solution, should the city center need more power. In addition, undergrounding is the trend in cities currently: that also implies issues with capacitive currents which are not an issue using DC.

There are two main approaches to be considered:

- Using MVDC grid as a backbone to integrate LVDC consumers / producers to reduce CAPEX and conversion losses for the connection of large DC loads within cities (e.g. EV charging stations).
- Support existing weak AC grids with the aim to avoid potential power quality problem and allowing power exchange between distribution line thanks to multi-terminal connections.

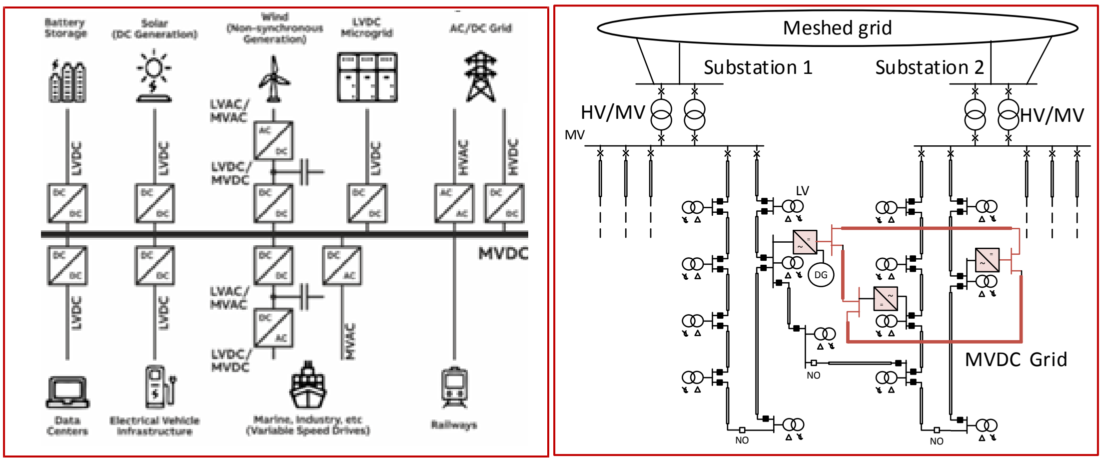

Figure 3 – Load connection in cities and multi-terminal MVDC connections

Application D – Remote load connections

Many isolated communities are not connected to the electrical grid and are strictly dependent on expensive local generation for their needs. The same applies for power supply to small islands.

By installing an MVDC transmission line with a low-cost extruded cable (island interconnection) or an overhead line, cheap electricity from the main-land grid can be imported and the local diesel generator can be shut down thus reducing costs for fuel transport, storage, and diesel generators maintenance.

For overhead line application, typical breakeven distance for choosing DC transmission over AC transmission is above 75-100 km with also a reduced visual and environmental impact thanks to compact overhead lines.

Application E – DC connection of renewables

Medium-sized distributed generation plants (wind and solar above 10-20 MW) are typically connected directly either to the sub-transmission level (above 100 kVac) or to a HV/MV substation on the MV side.

In order to avoid the expansion of the sub-transmission network, MVDC could be used to connect new Distributed Generation plants to existing HV/MV substation located further away.

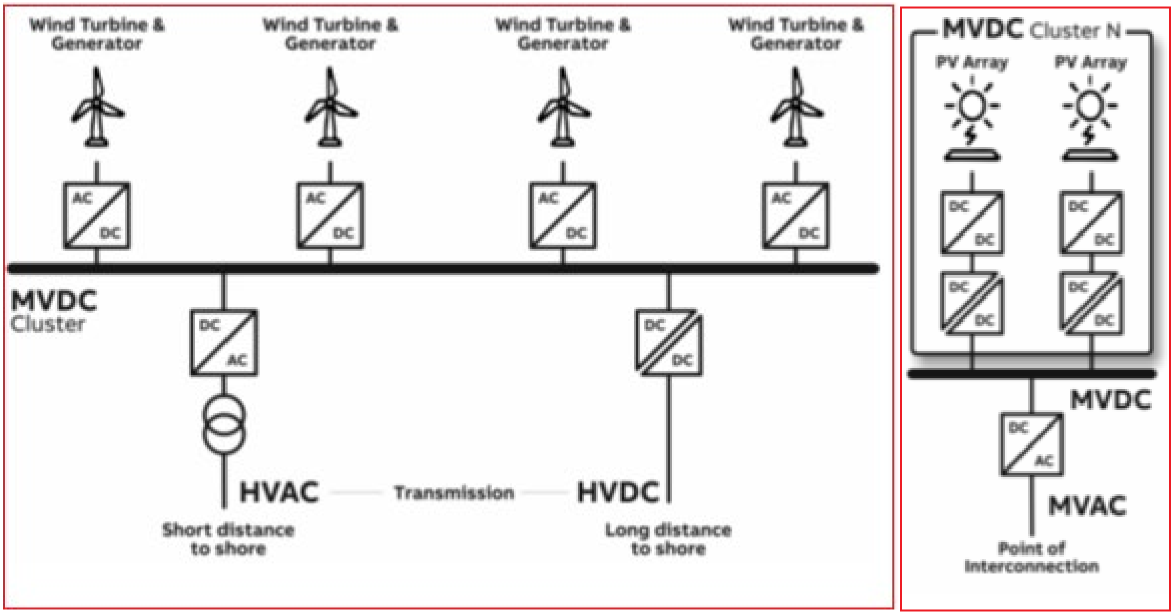

Figure 4 – Wind and solar MVDC collection

Main application cases would be:

- Offshore and onshore wind power: the use of a local MVDC grid within a wind turbine cluster could further improve the power collection efficiency and the overall cost.
- Solar: in large PV farms, the use of 1.5 kV solar panels has been quickly adopted to cope with strong cost pressure. In the near future, PV farms with even higher voltages around 3.5 kV are expected due to double glass bifacial PV module technologies.

Main benefits would be:

- Reduced space requirement inside wind turbine, since only rectifier required.
- Direct connection of high voltage PV panels to MVDC inverters
- Reduced losses in the collection grid through DC currents and less conversion steps

Application F – Industrial grid interties

Industrial grid interties consist in interfacing a utility grid to a non-utility grid by means of a power conversion system.

There are several potential cases to be taken into consideration, including but not limited to the following:

- Asynchronous links: in some specific cases, there is a need to exchange power between an industrial and a public grid at same or different frequencies, specifically when there is an unbalance between generation on one side and consumption on the other side. When this occurs, a grid intertie system will enable smooth power transfer, block the harmonics to propagate into the public grid, provide sufficient reactive power to the industrial grid and balance the local loads.

  An example of this application, is the two 19 MW grid coupling systems with 32 MVA STATCOM functionality that were installed in Indonesia to provide smooth power supply exchange and reactive power compensation between an arc furnace and a thermal/hydro power generation system. [4]

- Industrial Plant Relocation: when an existing industrial plant originally located in a 50 Hz (or a 60 Hz) country is moved to a 60 Hz (or a 50 Hz country) respectively, an industrial grid intertie is a viable option to the potential substitution of all the main industrial plant loads.

  An example of this application, is a 1250 kVA static frequency conversion system which has been installed in a textile production plant in Mexico to allow the relocation of an existing production line from Italy, without replacing or refurbishing any of the production machinery. [5]

- Microgrid connections: some microgrids might benefit from becoming grid connected to allow selling back to a local utility the excess of generated power or to buy electricity when local generation is not sufficient. STATCOM functionality to stabilize the local microgrids or allow the connection into the utility grid in full compliance with local grid code might also be required as well as nested microgrid or microgrid clusters linked with controllable power flow.

- Generations sets interface to grid: in emerging markets, power generation might be insufficient to serve the local industrial area needs. There are therefore the solution with re-locatable power plants or generation sets that might have been designed for a different frequency or where grid code compliance shall be ensured by means of static frequency converters.

- Grid simulators/test stands: some research or certification institutions need a laboratory where they can carry out specific tests on electrical grids or devices.

- Rotating Frequency Converter replacement: replacing old RFCs in order to achieve better energy efficiency during operation.

An example of such application, is a 5 MVA (Mega Volt Amperes) Static Frequency Conversion system which has been installed in a Navy Base in UK to replace an end-of-life rotating converter supplying several 60 Hz loads. [6]

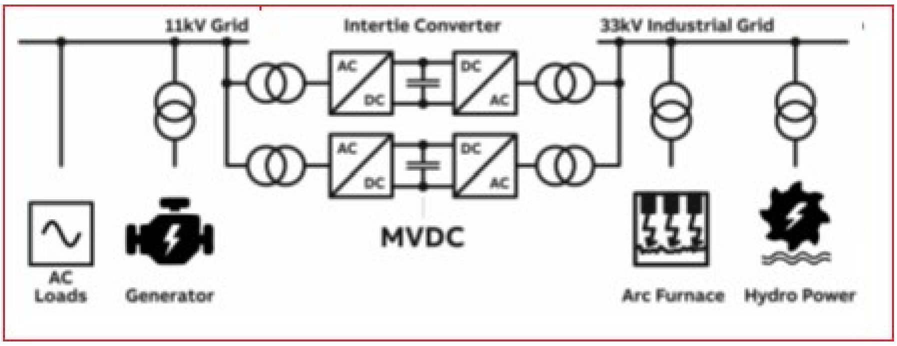

Figure 5 – Industrial Grid Interties

Application G – Power from shore

Typical offshore platforms are not connected to the mainland electrical grid and are strictly dependent on expensive local generation for their needs.

O&G industry is therefore looking to potential alternatives wherever feasible to connect to the mainland grid also in view of stricter environmental regulation in some selected regions.

There could be different approaches to ensure this connection:

- Installation of back-to-back converter off-shore using an AC subsea cable
- Installation of a MVDC point-to-point (P2P) converter with one terminal located off-shore (possibly transformer-less) and the other terminal on the mainland

Power from shore is already a well-developed application with HVDC Light technology already deployed to several oil & gas fields in the North Sea (latest conversion stations rated ±80 kilovolt and 100 MW). [7]

In both cases the main drivers would be:

- Reliable power supply with full control of P/Q off-shore.
- Capability to supply required overloadability for transformer pre-magnetization and large direct-on-line (DOL) pump/compressor motors
- Redundancy (embedded in power converter or external) to ensure that no loss of power occurs, also for safety reasons.
- Limited footprint available on the platform.

Conclusions

Industrial Grid Interties applications are quite common to solve specific grid interconnection issues, such as different frequencies or phase shifts between the local industrial site and electrical distribution grids. Such applications usually require a mono-directional power flow and power electronics devices allowing such interconnections are readily available on the market, thus allowing a fast solution implementation.

On the other hand, Medium Voltage Direct Current connections are finding their way in distribution and sub-transmission grid thanks to the first pioneering demonstration projects. The large-scale implementation of MVDC will facilitate the introduction to market of dedicated solutions designed for the various applications.

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