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REEL Demo – Romande Energie ELectric network in local balance Demonstrator

Deliverable: 6a2 Design principle of soft-open point

Demo site: Chapelle

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1 Description of deliverable and goal

1.1 Executive summary

The soft-open point is a conceptual device introduced in the first deliverable of this activity "REEL Project – WP6, Preliminary study for soft-open point deployment into REEL Demonstrator". A reduced-scale prototype device has been designed and assembled in order to test different control modes under laboratory conditions. The design relies on a two-level inverter structure previously developed by HEIG-VD. The control architecture distinguishes between three different local control modes.

1.2 Research question

The objective of the activity covered by the work in this report is to answer the following questions:

- How should the soft-open point system for the reduced-scale LV and for MV demonstration be designed?
- How can be a MV SOP demonstrator be implemented?

1.3 Comparison with other demonstrator activities

The SOP developed in this activity take an approach different and complementary to other approaches: the first prototype will be a reduced scale prototype.

This will allow for more different situations and scenarios to be tested as compared to a direct deployment into a real system where the topology cannot be changed and faults cannot be freely introduced into the system.

The building of a second protoype in MV will be studied in this activity. The building of this second prototype requires an additional sorce of financing. The mounting of an European project is foreseen. However, if the European project will not be achieved, and/or the size of the MV prototype will be too high, the LV prototype will be tested on the site.

1.4 SOP description

1.4.1 Soft-open point principle and operation

The soft-open point (SOP) is a power electronic device described in the report able "REEL Project – WP6, Preliminary study for soft-open point deployment into REEL Demonstrator". Some elements will be repeated here for the sake of clarity. The SOP main purpose is to permit a meshed (or looped) operation of radially operated distribution networks, i.e. open loops. As shown in Figure 1, the chosen normally closed variant of the SOP represents a way to decouple load flows and fault currents:

- SOP is closed in normal conditions, thus establishing a meshed/loop network topology for load flows
- SOP opens (faster than mechanical breakers that remain in the distribution system) in fault conditions, thus establishing a radial network topology for fault currents.

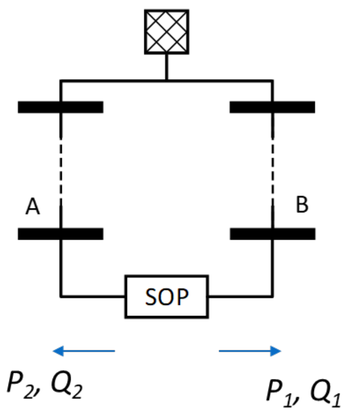


Figure 1 Illustration of the SOP inserted into a MV network

In preparation for the deployment of a full-scale prototype of the SOP, the interface between the SOP local control and the overall control is currently discussed with other REEL work package teams. Progress on this aspect is below expectations due to the required coordination with the overall demonstration activity in REEL that have been delayed during 2017. The final choice of the SOP location will also play a role in this discussion.

1.4.2 Soft-open point possible structures

This section presents and compares the different system topologies suitable for a Soft-Open Point (SOP). A quick review about power converter topologies is also proposed.

A SOP can be made in principle with a series, a shunt or a hybrid FACTS (Flexible AC Transmission System) controller. Each system topology has its own advantages and disadvantages. Main considerations for the choice of a SOP topology are the following:

- Efficiency: Power converters operate with losses, and heat must be evacuated; water cooling is not available in substation environment and it may be problematic,
- Cost: Downsizing of power converters for the same amount of power transferred can be required,
- Reliability: SOP internal fault must be managed. To be clarified if it is necessary to ensure an uninterrupted service
- Safety : Power converter inside a sub-station must demonstrate to be safe.
- Fault isolation: Power quality issues and grid fault (short-circuit) isolation between feeders must be assessed
- Flexibility: Control algorithms and ancillary services must be provided to DSO,
- Volume: Room in substation is limited; adding transformer and other issues related to the functioning of the power converter can be problematic.

Table 1 gives a clear view of advantages and disadvantages of seven type of FACTS controllers that could be used for a SOP system. Moreover, many variants and combination of those basic topologies exists. Those variants reduce basic topologies disadvantages but increase complexity of the system.

Table 1- Comparative study of facts Controller for a SOP

	SSSC	MB2B	STATCOM	UIPC	HPFC	IPFC	UPFC
Control mode	I	RP,AP,U	U	RP,AP,U	RP, U	RP, U	RP,AP,U
Independent control of voltage feeders	NO	YES	NO	YES	YES	NO	YES
SOP efficiency	+++	++	+++	+	++	++	++
Improve grid stability	TS,DS, SS	TS,DS, SS	SS	TS,DS, SS	TS,DS, SS	TS,DS, SS	TS,DS, SS
Continuity of service	MESHED	RADIAL	MESHED	MESHED	MESHED	RADIAL	MESHED
Downsizing of power inverter	YES	NO	YES	YES	YES	YES	YES
Power quality (harmonics and asymmetries isolation…)	NO	YES	NO	NO	NO	NO	NO
Reducing short circuit current	++	+++	+	++	++	++	++
Overall volume	+++	+	+++	+	++	++	++

I *: Current,* ***RP*** *: Reactive power,* ***AP*** *: Active power,* ***U*** *: Voltage,* ***TS*** *: Transient stability, D****S*** *: Dynamic stability,* ***SS*** *: Static stability. Comparaison index :* ***+++*** *: Higher,* ***++*** *: Intermediate,* ***+*** *: lower.*

- **SSSC/ D-SSSC** : (Distributed) Static Synchronous Series Compensator is a series connected facts controller, including a three-phase grid connected power inverter or three single-phase grid connected power inverter for the D-SSSC. Grid connection requires transformer(s) [1].
- **MB2B** : Multiple back to back is a shunt connected facts controller comprising at least two three-phase power inverter. The most widespread structure is the Back-to-Back (B2B) with two power inverter. Grid connection can be transformerless or not [2].
- **STATCOM / D-STATCOM** : (Distributed) Static synchronous compensator is a shunt connected facts controller including a three-phase grid connected power inverter or three single-phase grid connected power inverter for the D-STATCOM. Grid connection can be transformerless or not, but most widespread STATCOM topology make use of transformer(s) [3].
- **UIPC** : Unified Interphase Power Controller is a series-shunt device including three three-phase power inverter connected to the grid by transformers. Moreover capacitors and inductors are needed too [4].
- **UPFC** : Unified Power Flow Controller is a series-shunt device including three three-phase power inverter connected to the grid by transformers [5].
- **HPFC** : Hybrid Power Flow Controller is a series-series facts controller with two three-phase inverter and connected to the grid by transformers. Passive elements are required [6].
- **IPFC** : Interline Power Flow Controller is a series-series facts controller with two three-phase inverter and connected to the grid by transformers [7].

Compared to others topology, MB2B or B2B has three unique characteristics. The first one concerns the short circuit current, which is not impacted when feeders are electrically connected through power inverters. Meaning that grid protection (overcurrent protection) in Rolle grid does not need to be tuned or updated. B2B topology also make it possible not to propagate harmonics or voltage asymmetries from a feeder to another. However, power converters have to be designed to support all the power transferred

between feeders. In other words, power converters cannot be downsized, limiting the use of this topology to medium and low voltage grid.
MB2B, IUPC and UPFC offer higher flexibility in grid control. They are able to provide independent active power flow control, reactive power compensation and voltage regulation under normal grid operating conditions. In case of SOP failure, continuity of service must be ensured. Current transformers used in UIPC and UPFC have to be bypassed. Grid topology during SOP fault is meshed/looped. With B2B topology, the default grid topology during SOP fault is radial. However, with a bypass grid topology is meshed/looped. It is worth mentioning that a battery could be easily added and designed with B2B topology. Adding a battery increase SOP flexibility and decouple power of feeders. B2B topology was deemed the only one possible for REEL demonstrator.

1.4.2.1 Possible power converter topology for SOP

The choice of power converter structure determines many features, such as SOP efficiency, harmonic content, electromagnetic perturbations, reliability and overall volume of the system. This part is a review about prototypes and structures already employed for a SOP system. For reliability, efficiency and control loop dynamic reasons, Voltage Source Inverters (VSC) are generally used in SOP system. There are six kinds of VSC structures, which can be broadly classified into “single level inverter” and “multilevel inverter”. The first family include the well know two-level inverter and two-phase inverter with Scott or Leblanc transformer. The last structure has disappeared in countries where three-phase is available because it is less flexible and requires a significant capacity to maintain DC bus voltage within +/- 1 [%] of its nominal value.
The second family refers to multilevel converters: Neutral-Point Clamped converter (NPC), Flying Capacitor converter (FC), Modular Multilevel Cascade converter (MMC) and hybrid converters. There are several variants for each of those structures.
In [8], a theoretical and comparative case study about passive components sizing and global efficiency of SOP is proposed for a Two-level inverter, NPC and MMC structure.
The following specifications and assumptions were made:

- DC bus voltage: 20 [kV],
- Grid line to neutral voltage: 8.95 [kV],
- Nominal Power : 12 [MVA],
- IGBT : 3.3 [kV] / 1200 [A] from Toshiba,

- LCL filter,
- Harmonic compliance: IEEE 519 et IEEE 1547.

The results of the study are presented in Figure 2 and Table 2.

Table 2- AC and DC filter requirement.

	Inverter side inductor [mH]	DC bus capacitors [mF]
2-Level	10	1x 0.2mF @20kV capacitor of 40kJ and 2.2 m^3
NPC	2.5	4x 2.73mF @5kV capacitors of 4x34kJ and 3.8 m^3
MMC	1	36x 4mF @1.7kV capacitors of 36x5.8kJ and 5.8 m^3

The different topology has similar overall volume but with different sizes for DC and AC side filters. Space taken just by filter components could be problematic in substation. In Figure 2 power losses are estimated for each major component. Multi-level converters save considerably compared to two-level inverter due to reduced switching loss. Losses in filter represent 18% of overall loss. Cooling requirement could be problematic in sub-station, especially for high power SOP.

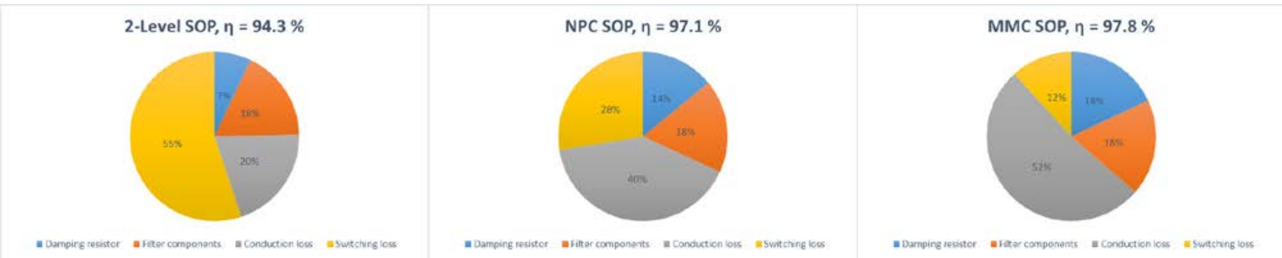


Figure 2-SOP efficiency for a 2-level, NPC and MMC structure

This study illustrates the interest of multilevel structures for SOP.

1.4.2.1.1 Two-level inverter

This is the most basic structure for a voltage inverter. Figure 3 illustrates the internal structure of a two-level inverter and a SOP prototype using this structure.
Power semiconductors are limited by their voltage rating. It is possible to find IGBT type semiconductors supporting up to 6.5 [kV]. In the case of the Rolle grid, this implies a minimum (excluding safety margin) of about fourty power transistors for one-half of SOP. It is possible to reduce the semiconductor voltage constraint by using a transformer

between inverter and grid. However, for a given power, reducing AC voltage will increase current trough IGBT and ohmic losses. Optimization is needed to define for a given volume the maximum efficiency.

This structure has the following advantages:

- Simple control structure,
- Capacitors can be pre-loaded all together,
- Reliability (less semiconductor).

However, this structure have also many drawbacks:

- Efficiency,
- Common and differential filter size,
- Not tolerant to faults,
- High $\frac{du}{dt}$ (Electromagnetic perturbations).

Prototype of Figure 3 is a 1 MVA transformerless SOP. Line to line grid voltage is 6.6 [kVrms]. SOP include 48 IGBT with a switching frequency of 1350 Hz. Overall volume is 18.65 [m^3], being a power density of 0.0187 [m^3/kW].

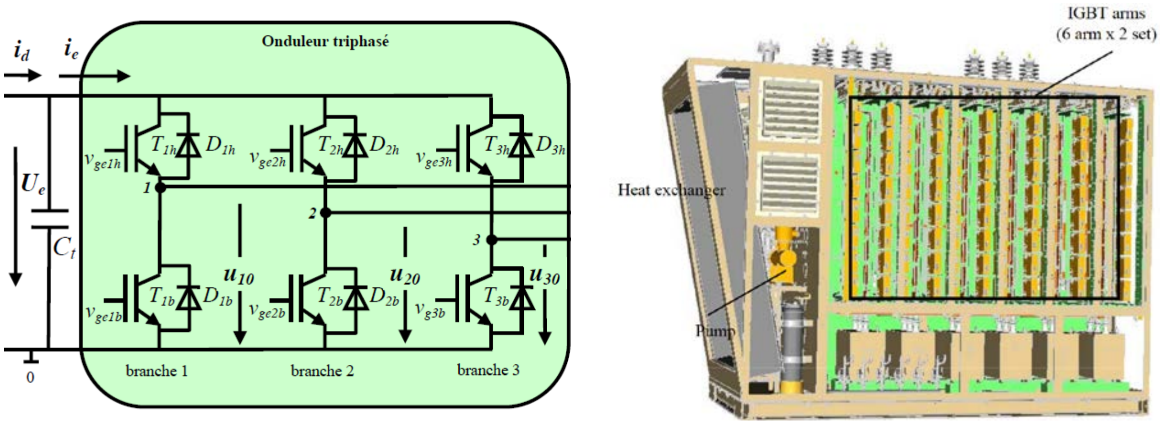


Figure 3- Left picture: 2-level inverter topology; Right picture: SOP using 2-Level inverter [9]

1.4.2.1.2 Neutral Point clamping inverter

To overcome the main disadvantages of the two-level inverter and to overcome the limits of semiconductors, multi-level converters have been developed. A two-level inverter applies rectangular-shaped voltages to the output of each branch. The amplitude is imposed by the DC-link. Rectangular-shaped voltages induce a wide harmonic content for current supplied by inverter. Multilevel inverters divide those discrete values in order to get branch voltages as close as possible to a sinusoidal voltage. The NPC (type I) is the first multilevel converter that has been commercially available. The two level converter inspires its structure. Figure 4 shows a three-level NPC ($U_{dc}/2$; 0; $-U_{dc}/2$). The addition of two diodes, two transistors per phase and a midpoint between diodes and capacitor of the bus dc provides this third state.

In theory, the NPC converter concept can be extended to have an infinite number of levels [10], in reality the NPC converters very rarely exceeds the seven levels because of the complexity of the structure. In an effort to overcome this issue the NPC type T converter has been proposed [11]. However, branch switches must support all DC bus voltage like for two-level inverter. Interest in T type NPC is mainly for low voltage applications.

This structure has the following advantages:

- Capacitors can be pre-loaded all together,
- Higher efficiency (compared to Two-level inverter),
- Lower electromagnetic perturbations (compared to Two-level inverter),
- Smaller AC filter (compared to Two-level inverter).

Main drawbacks are:

- More complex control structure (third harmonic management and stabilization of the DC-link required),
- Limited number of level in practice,
- Reliability,
- DC bus sizing,
- Not tolerant to faults.

Figure 4 is a back-to-back VSC-based conversion system in Eagle Pass, Texas [12]. This installation makes use of ABB's early HVDC-light topology, which consists of a back-to-back arrangement of 3-level neutral-point clamped IGBT based VSCs, operating at a 1.5 kHz switching frequency. This back-to-back link can exchange 36 [MW]. An idea of the size of the individual components involved with a medium voltage multi-megawatt back-to-back converter installation is given in Figure 4. As can be seen, the footprint of the whole converter is not negligible.

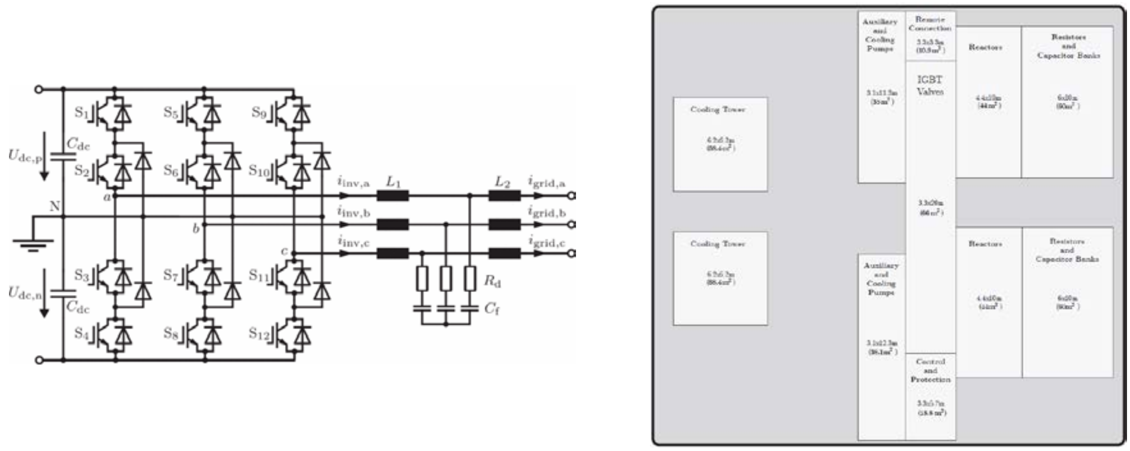


Figure 4-Left picture: 3-level NPC inverter topology; Right picture: Sizing for a 36 MW/15.9 kV back-to-back utility-scale conversion system [12]

1.4.2.1.3 Modular multilevel cascade converter

MMC converter has been introduced in 2003 [13]. According to Akagi, the whole MMC converter family can be classified from circuit configuration as follows: single-star bridge-cells (SSBC), single-delta bridge-cells (SDBC), double-star chopper-cells (DSCC), and double-star bridge-cells (DSBC) [14].

In the context of REEL demonstrator (SOP without storage), Double-Star Chopper-Cells (DSCC) and Double-Star Bridge-Cells (DSBC) structures are the most relevant.

The two-level and NPC inverters share the caracteristic of being natively non-tolerant to switching hardware faults. The DSCC and DSBC structures offer hardware redundancy. In addition, in the event of a short-circuit on the DC bus, the DSBC structure is able to “block” the fault current, without destruction of the converter. Nevertheless, since this structure requires twice as much semiconductor as the DSCC structure, the use of this structure is limited to applications where the risk DC bus fault exists. For REEL demonstrator, a DSCC structure is suitable.

This structure has the following advantages:

- Highest efficiency,
- Lowest electromagnetic perturbations,
- Smallest AC filter requirement.
- Tolerant to fault.

Main drawbacks:

- Complex control structure (both hardware and software),
- High capacity needed for submodule,
- Cost investment.

2 SOP Case study

The system level study has be described in [15]. SOP REEL demonstrator will be settle in to 336-Buttes substation (node 18). In order to define SOP specifications and its impacts on the Rolle grid, Rolle grid has been modeled in Power Factory software. It has been proven that SOP is a pertinent solution for meshed/loop grid topology under normal operating conditions, while protecting against the negative effects of loop topology when a fault occurs on the grid.

2.1 SOP Nominal power

SOP is not intended to support the nominal power of the HT/MT transformer. In the worst case, it may assume the full power of the most loaded feeder, being 1.9 MVA in the current Rolle grid (feeder 51). Realistically, the role of SOP is to guarantee a satisfactory level of voltage at grid nodes. For this purpose, the SOP power could be reduced.

2.2 Soft-open point control functions

The basic operation strategy of the normally closed SOP are:

- The closed state is the normal operation state, which allows a reduction of ohmic losses in typical load and generation situation as well as a reduction of voltage variation due to load and generation power.
- The SOP changes to the open state when a fault is detected.
- The short-circuit contribution is controlled, i.e. the short-circuit current contribution is limited approximately to the rated current of the SOP.
- The SOP can disconnect fast, independently of the operation of the existing distribution system's protection system.

If implemented using full converters (e.g. back-to-back two level inverters or modular multi-level converters), the SOP can be extended with further control features including e.g.:

- Reactive power management / Voltage control
- Loss reduction / optimization by controlling the power transit through the SOP
- Series compensation

These functionalities are achieved by using one of the control modes of the SOP [16]:

- P-Q mode: in this mode, the active and reactive power through the SOP can be controlled.
- Switch mode: in this mode the converter will either act as a closed switch (by letting any current smaller than the maximum operating current flow and ensuring that the voltage difference across the SOP is zero.
- Z mode: in this mode the SOP behaves as a (current limited) impedance.
- U mode: in this mode the voltage on both sides of the SOP is controlled to the reference value.

2.3 Soft-open point control architecture

Figure 2 shows the preliminary control architecture of the SOP.

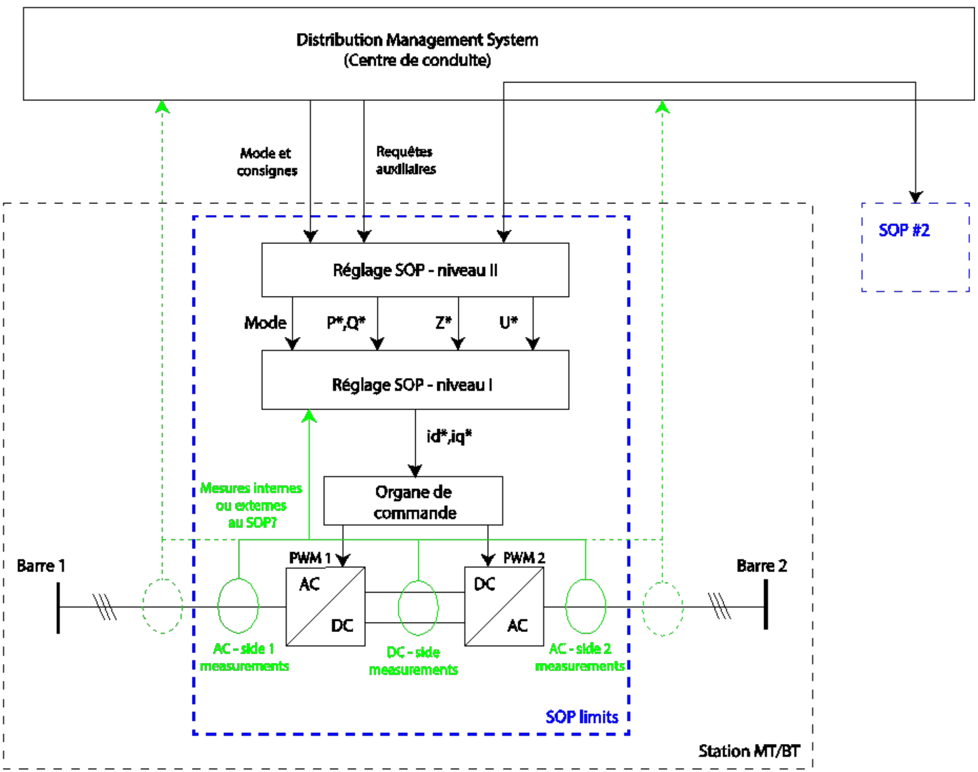


Figure 2: Control architecture of the SOP.

The architecture has been defined and its implementation is planned at a further stage (i.e. full-scale demonstrator). The inner control of the SOP will generate current references in the d,q rotating reference frame. The inner control will receive the control mode as described above and derive the d,q references. The outer local loop will select the mode of the SOP and the required reference values based on information from the fault detection system, local measurements and possibly other interfaced systems as the distribution management system or others. A communication to other SOPs is also planned.

2.3.1 SOP- Control mode

To our best knowledge, the scientific literature and patents only mention three modes of control:

- P/Q : Each inverter has its own controllers for active and reactive power. If SOP does not have a storage element connected to the DC bus, the active powers exchanged must be equal in amplitude and opposed in sign.
- Voltages balancing: the objective is to obtain an equal voltage (in amplitude) at points of common coupling of the grid with the SOP. The definition of voltage reference depends on the expertise of the DSO.
- Load balancing: It is mentioned in [17] an algorithm balancing the total load between the two feeders. Method and the purpose are not described. However, it is clear that knowledge (high-level controller) of the grid is needed to set SOP references.

These modes of control are based on a more or less in-depth understanding of the grid, making it difficult to introduce the SOP into an already complex electrical grid. Moreover, their introduction in DSO simulation tools of simulation is problematic. We propose two new control modes that overcomes those problems, ON / OFF and IMPEDANCE mode.

2.3.2 ON/OFF mode

Currently, meshed/ loop grid topology is obtained by an ON/OFF switch control. It is quite possible to emulate that behavior with a SOP. SOP references are simply an open / close command. This type of control is perfectly mastered by a DSO and elementary to implement in planning software.

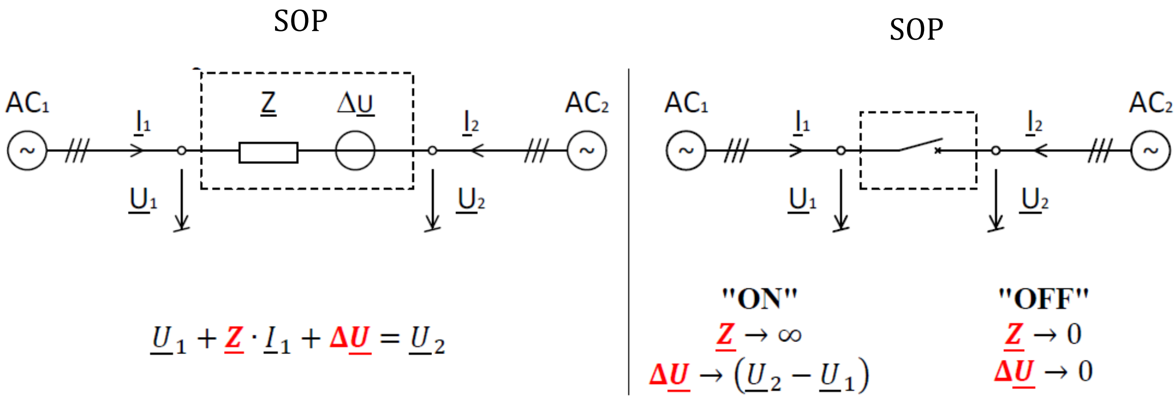


Figure 5: ON/OFF mode principle

ON/OFF control mode imposes two conditions:

- A voltage amplitude identical at the common coupling points ($|\underline{U}_1| = |\underline{U}_2|$),
- A zero impedance ($\underline{Z} = 0$), which can be reformulated by a voltage phase difference equal to zero at common coupling point ($\theta_{U1} = \theta_{U2}$).

In the case of a lossless and purely inductive grid, it is possible to relate the active power to the power angle ($\delta = \theta_{U1} - \theta_{U2}$) and conversely the reactive power with the voltages amplitude at the points common coupling. In a real grid including losses, a coupling appears between the active power and the voltage at the common coupling points, as well as between the reactive power and the power angle. The proposed model takes into account this coupling.

Figure 6 illustrates the simulations obtained in ON / OFF control mode. The parameters used for the grid are those of the Rolle grid, standardized for low voltage and a nominal SOP power of 10 [kVA]. The SOP is ON at t = 0.5 [s]. Figures I1 and I2 show the instantaneous currents at the common coupling points. These currents are compared to those obtained by replacing the SOP with an ideal switch (dashed lines). After a transient of about 200 [ms], the currents obtained with the SOP are equal (phase and amplitude) to those obtained with an ideal switch.

Subfigure U1-U2 shows the amplitudes of $\Delta\underline{U}$ obtained with a SOP (red curve) and a switch (blue curve). Before meshed/loop topology of the grid we notice an amplitude difference of 0.75 [V], which tends to 0 [V] when the SOP emulates the behavior of a switch.

Subfigure δ shows the phase difference of $\Delta \underline{U}$ obtained with a SOP (red curve) and a switch (blue curve). Before meshed/loop topology of the grid by the SOP we see that the power angle is about 0.003 [rad] and tends to 0 [rad] when the SOP emulates the behavior of a switch.

The simulations confirm that an SOP system can emulate the behavior of a switch

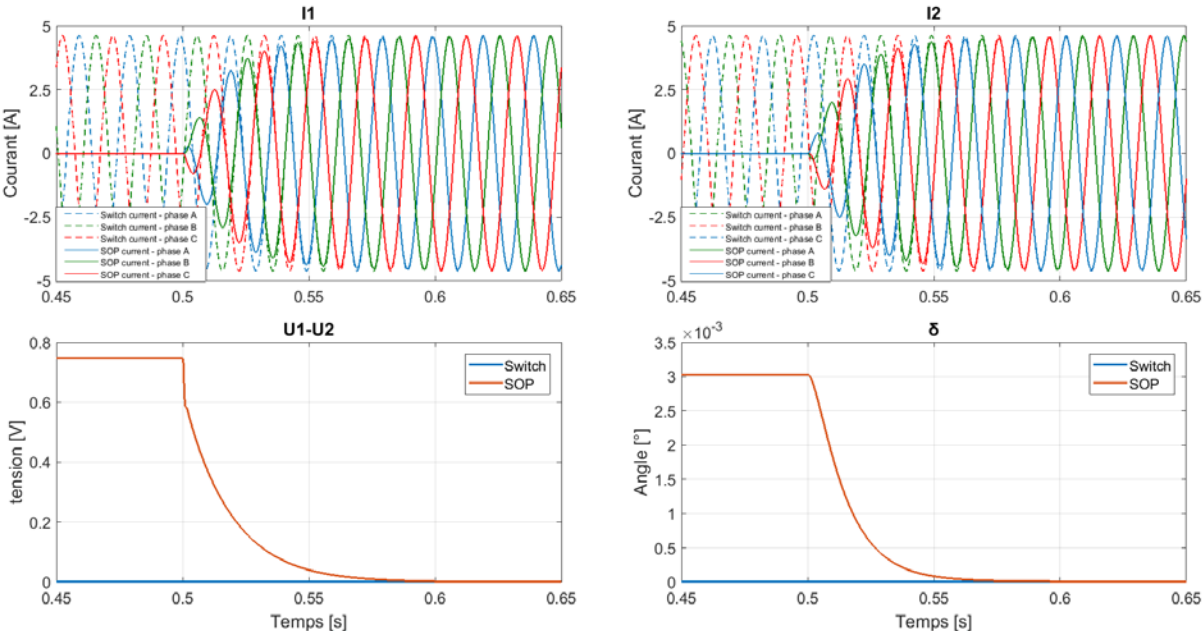


Figure 6: ON/OFF mode results

2.3.3 IMPEDANCE mode

The emulation of an impedance, of variable nature and value, by an SOP would be interesting for:

- Damping and/ or shifting harmonic resonances,
- Power flow control between feeders.

A P/Q control can also achieve this latter possibility. However, as already mentioned above, the DSO simulation and planning tools are not suitable for the direct integration of a power electronics converter. On the other hand, implementing an impedance for this purpose is quite easy. In order to limit the power transferred between feeders it is necessary to emulate the behavior of an inductor.

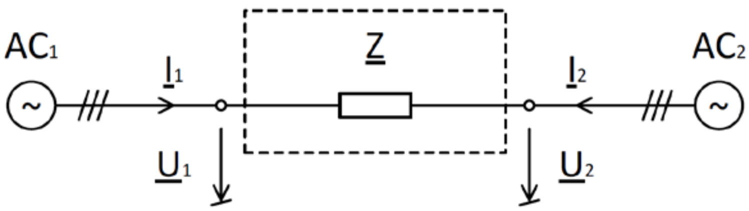
In order to respect the reactive power pricing, passive compensation systems are set up. Power electronics converter are responsible of harmonic currents circulation in grids and transformers. Those harmonics disrupt the operation of many devices. In particular, reactive energy compensation systems are extremely sensitive because their impedance decreases proportionally to the harmonic rank. Under certain circumstances, resonance phenomena can occur resulting in high voltage distortion and overcharging of capacitors.

The impedance control mode shifts the resonance frequency of the grid by influencing its impedance. Indeed, the resonance frequency for an LC circuit is determined by the equation below:

$$f_{res} = \frac{1}{2\pi\sqrt{LC}}$$

Any modification of the inductance (L) changes the value of the resonance frequency.

This setting mode can also emulate the dynamic behavior of the impedance. However, the time constant of the emulated impedance has to be greater (> 5) than the current loop dynamic.



$$\underline{U}_1 + \underline{Z} \cdot \underline{I}_1 = \underline{U}_2$$

Figure 7: IMPEDANCE mode principle

La Figure 8 illustrates results obtained with impedance mode. The parameters used for the grid are those of the Rolle grid, standardized for low voltage and a nominal SOP power of 10 [kVA]. The SOP is ON at t = 0.5 [s]. The emulated impedance bandwidth is limited to 55 [Hz] in this example. Grid voltages are pure sinusoidal waveforms.

Figure 8 shows the instantaneous currents I1 and I2 at the common coupling points. Currents trough SOP are compared to those obtained by replacing SOP with an ideal impedance of 300 [µH]. After a transient of about 150 [ms], the currents obtained with the SOP are equal (phase and amplitude) to those obtained with an ideal impedance.

In this example, the SOPS dynamics is limited by the control loop and does not represent inductor dynamics.

The simulations confirm that an SOP system can emulate the behavior of an impedance at 50 [Hz].

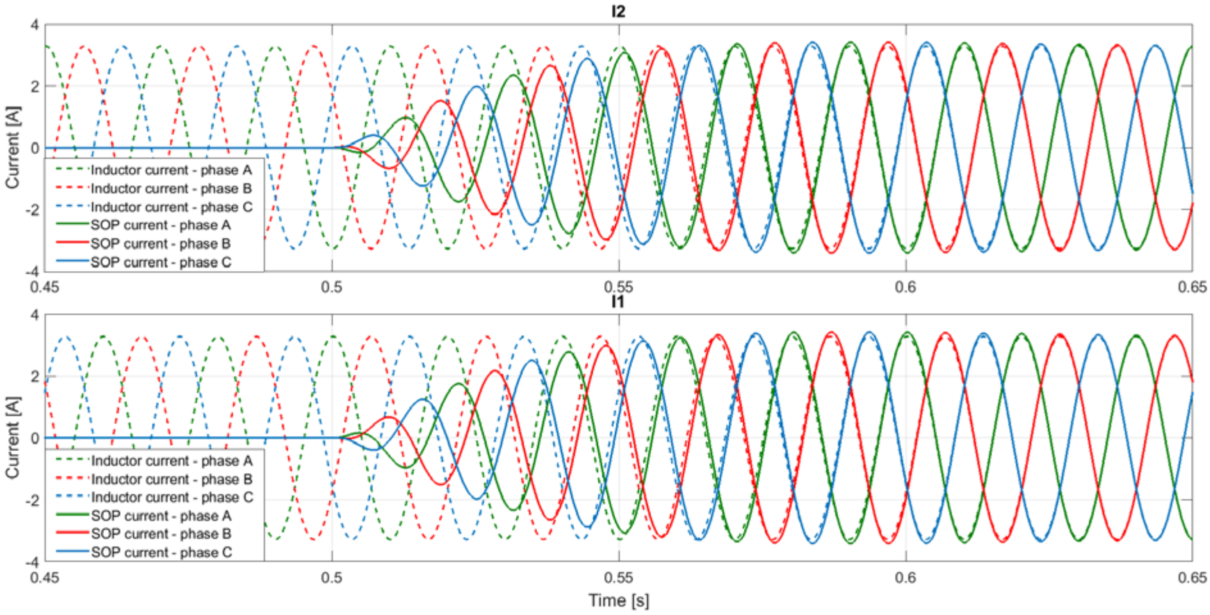


Figure 8: IMPEDANCE mode results, L_{ref} = 300 [µH].

3 LV Soft-open point design

A 10 [kVA], transformerless, two-level, low voltage back-to-back SOP has been designed by HEIG-VD. The prototype may integrate a storage section.

3.1 Hardware

Designing of LV SOP is based on PENELER-Ond inverter. Actually, two inverter in a back-to-back configuration have been used. All the detail of the design of the inverter can be found in [18], and they will not be repeated here. Additional information on the LV SOP system will be presented in [19]. The main difference resides in the using of a different kind of microcontroller, a TI TMS320F28379D. This microcontroller has two cores, each core can control one of the two inverters.

A DC/DC converter connecting a battery to the DC link has been designed too, and is under realization.

The two back-to-back inverter are shown in the electrical cabinet, as shown in Figure 9. The prototype volume is not optimized to favorite the accessibility of the various components. According to simulations, SOP efficiency of the system is estimated at 95.8 [%] at 10 [kW]. In the same way, the theoretical THD is less than 4 [%] at 10 [kW]. The first electrical checks are conclusive. The SOP control card is different from the Peneler version. It makes use of a MicroController DSP Unit (MCU) from Texas Instruments, TMS320F28379D.

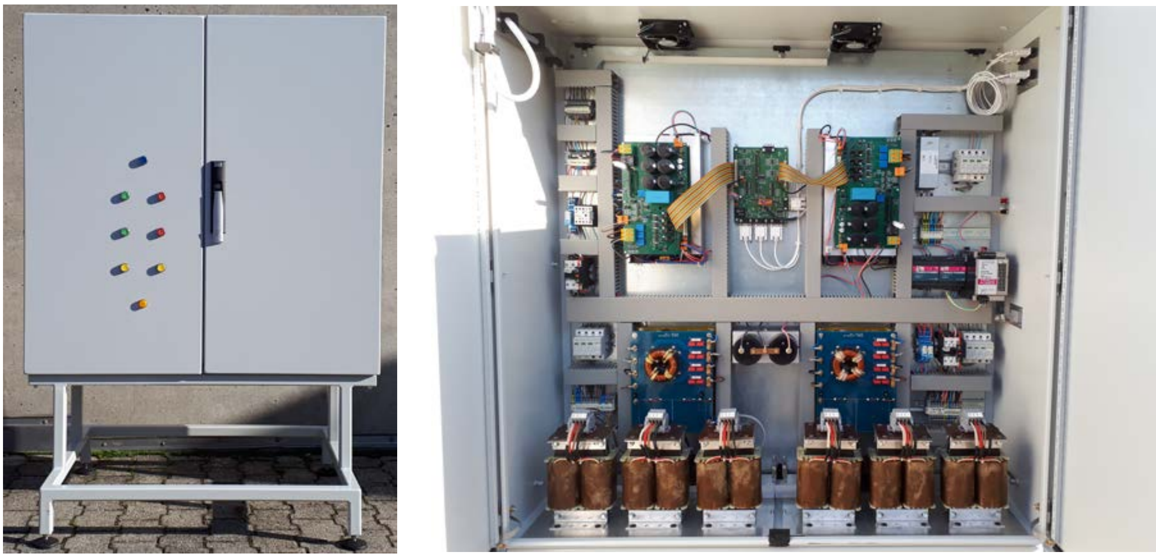


Figure 9: 10 kVA SOP prototype

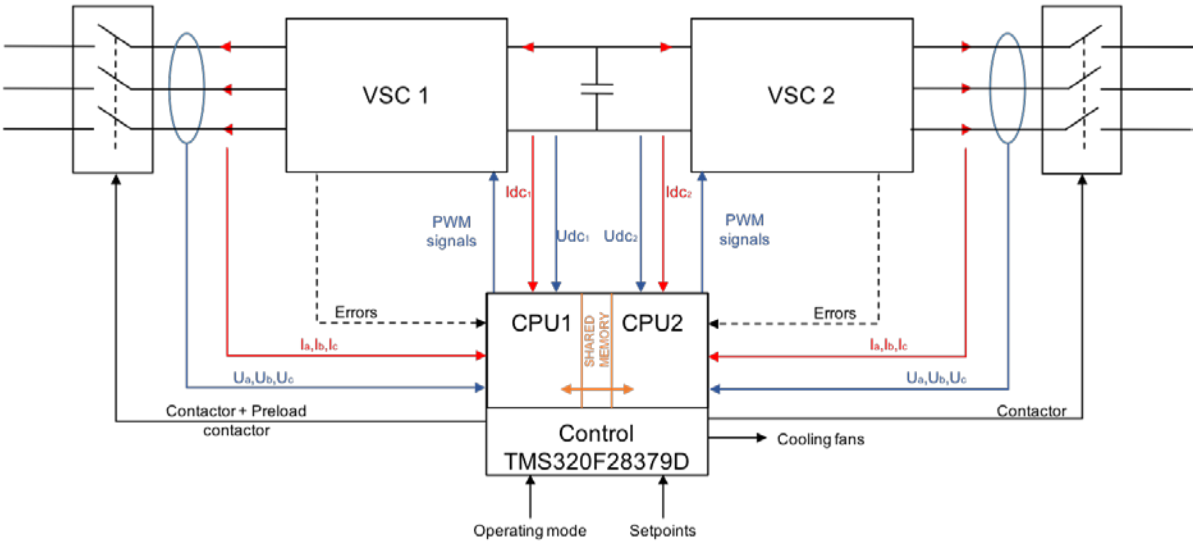


Figure 10: SOP schematics (principle).

In Figure 10 the principle schematic is shown. The MCU includes two processors with a shared memory area. ON/OFF command, operating mode selection and setpoints are covered by CAN communication. A second CAN bus (not shown in Figure 10) provide communication with the electrochemical accumulator and its converter. SOP firmware is currently under development.

3.2 Soft-open point laboratory testing and demonstration

Experimental laboratory tests are started at the beginning of March 2018.

They will be the subject of a future communication.

4 MV Soft-open point design

As already described in section 2, he realization of the MV SOP requires the mounting of an European project. This means that a collaboration with a major Power Electronics industrial partner is required. This is also necessary because the finances actually budgeted for this prototype are not enough for a MV power converter. The attemptto mount an European project is ongoing.

Two Italian power electronics manufacturers have been contacted, namely ASI NIDEC, (Cinisello Balsamo, Milan) and OCEM (Bologna). The two manufacturers proposed two similar solutions, based on two back-to-back NPC converters, rated 3kV, 3MVA, with two coupling transformers 3-24kV. The costs of the two solutions is about 1-1.2 millions of euro. The whole system, including transformers and auxiliaries, can be installed in two 20 feet standard container.

If the European project cannot be achieved, the MV voltage SOP option will not be achievable. As an alternative, the LV SOP system can be tested in a LV grid. However, other actions involving possible Swiss partners are under evaluation.

5 Achievement of deliverable:

5.1 Date

LV SOP prototype design: 1.3.2018.

5.2 Demonstration of the deliverable

The own funding and a part of the third-party funding of HES-SO Yverdon and Fribourg provides the manpower and the material for the studies associated with the soft-open point reduced-scale prototype discussed in this report.

The MV SOP deliverable planned later in the project is under discussion (see chapter 4). The experience with the LV prototype have been integrated into the preparation of this full-scale prototype.

As an alternative, the LV deliverable could be tested on the REEL site.

6 Impact

The design of the SOP reduced-scale prototype is an initial step to the design of the full-scale prototype. It also permits to start the testing of the SOP in the laboratory environ-ment.

The contents of the report is now used for the discussions with potential industrial part-ners for the manufacturing of the full-scale MV SOP demonstrator.

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