EPRG-PRCI-APGA
23rd Joint Technical Meeting
Edinburgh, Scotland
6–10 June 2022

EPRG-PRCI-APGA
23rd Joint Technical Meeting
Edinburgh, Scotland • 6–10 June 2022

ASSESSING HIGH VOLTAGE DC INTERFERENCE RISKS ON BURIED PIPELINES
PAPER NUMBER: 08

Christophe Baete*
Elsyca Inc.,Wijgmaal Leuven, BE

* presenting author

ABSTRACT

High voltage DC (HVDC) powerline systems typically transport energy over long distance with a smaller ecological footprint than the high AC voltage counterparts. There are 187 operational or planned HVDC systems worldwide causing a potential safety and corrosion risk for pipelines. These threats often occur unexpectedly when the operating mode of the HVDC change. Computational modelling technology was used to define the operational conditions of the HVDC system that lead to integrity and safety threats and how these can be properly mitigated.

DISCLAIMER

BACKGROUND

High Voltage DC (HVDC) powerline transmission systems typically transport large amount of energy (megawatt's) over long distances with less power loss and smaller ecological footprint compared to HVAC (High-Voltage Alternating Current) systems. However, transformers are required at the beginning and end of the line to make the conversion/inversion of the energy for transportation/utilization possible. Basically, the AC power enters the DC station at the rectifier which converts the reactive to active power. The active (DC) power is then transmitted via a high voltage overhead conductor or subsea cable towards the inverter. At the end of the transmission line the active DC power enters the inverter where the DC active power is converted back to AC reactive power.
HVDC systems may potentially cause corrosion and safety threats on buried pipelines. Unlike other third party DC systems, HVDC systems may cause pipeline corrosion even when the power line system is at long distance away from the pipeline. In many HVDC systems DC stray current corrosion and safety risks on a pipeline occur unexpectedly because these events are occurring when the HVDC system operates in a temporary mode or when a fault occurs in the system. Safety threats only occurs when a pipeline is running parallel in close proximity with an overhead HVDC line

IMPACTING HVDC SYSTEMS

A variety of HVDC systems exists depending on the level of energy that needs to be transported. One exception is the back-to-back HVDC system used to connect two different AC power nets operating at different frequency (50Hz vs 60Hz). The following typical HVDC systems are operational:

- monopolar HVDC systems (older type)
- bipolar HVDC systems (most common)
- ultra-high voltage DC systems (UHVDC)
- back-to-back HVDC system
- modular multi-level converters (MMC)

Worldwide there are 149 HVDC systems operational which may form a potential threat to pipelines. Table 1 shows that the majority of the systems is operational in Asia and Europe. Figure 1 shows the rated current of the different HVDC systems. In Europe, the first systems were of the monopolar type with relative low power capacity (< 1000MW) and DC current loads (<1500 A) but they operate all with ground return. Asia is an upcoming market with India and China ahead. Today about 50% of the HVDC systems have the bipolar configuration with ground return currents that may reach up to 5000 Amps. Systems with ground return may cause corrosion risks on buried pipelines.

	Africa	Australia & Oceania	Asia	Europe	North America	South America
Operational	3	5	54	53	17	3
Planned (<2020)	0	0	1	9	4	0
Total in 2020	3	5	55	62	21	3

Table 1 - overview of HVDC transmission systems per continent (extracted from https://en.wikipedia.org/wiki/List_of_HVDC_projects)

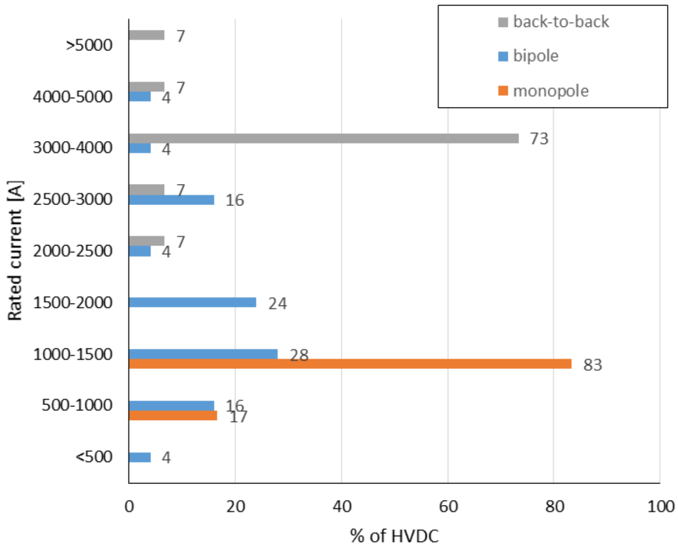

Figure 1 - overview of existing HVDC system types ranked by current rating

Monopolar systems

In monopolar systems the negative pole can be either the ground or a low voltage DC line. Systems with ground return are often of the older type of HVDC systems transmitting DC power from one shore line to another. The HVDC electrode is most often installed in the sea to minimize the ground potential rise in the surrounding area. More recent monopolar HVDC systems use metallic return (third cable) for the low voltage pole but a grounding on the DC side is still required for compensating unbalancing currents between the negative and positive pole.

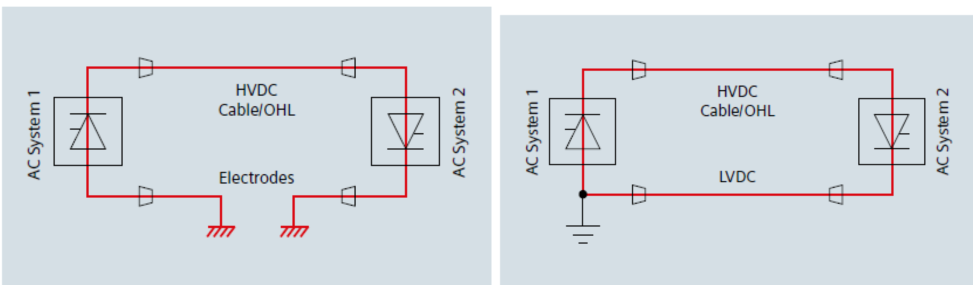

Figure 2 - monopolar HVDC system (left: older type, right: newer type)

Bipolar and UHVDC systems

A bipolar system is basically a combination of two monopolar systems with transmitted DC voltages of the same amplitude but of opposite sign. A bipolar system has a conductive path between the two poles to compensate for unbalanced currents. Under normal bipolar operating conditions, both poles have equal current but in practice an unbalanced current up to 5% of the rated current can flow from inverter to rectifier. The carriage of the unbalanced current can be achieved in two ways. Either the current flows through the ground via HVDC ground electrodes, or the unbalanced current is carried by a third overhead conductor wire, the so-called Dedicated Metallic Return (DMR). The former system is most often used because the cost for a HVDC ground electrode is in most cases lower compared to the cost of a DMR cable mounted on the towers, especially over longer distance. The latter system does not require HVDC electrodes which eliminates the risk of DC stray current on buried pipelines.

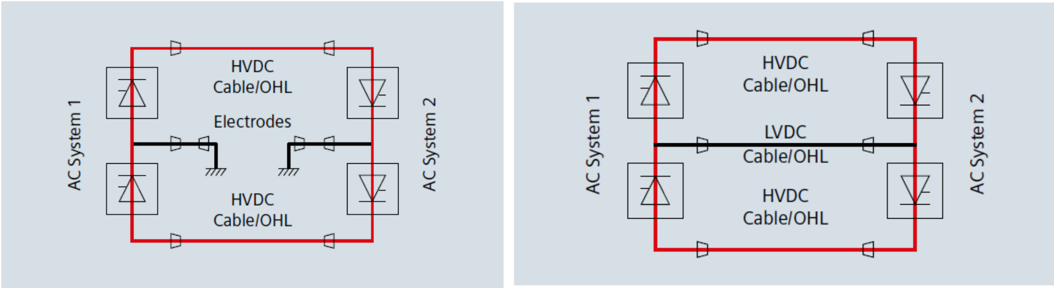

Figure 3 - bipolar HVDC system with ground electrodes (left) or dedicated metallic return cable (right)

Bipolar systems can temporarily operate in monopolar mode when maintenance is required on the overhead line or when a shortage in the system has occurred. One pole can continue to transmit half of the rated power when the other one is out of service. That is, each monopolar system can operate as an independent system but a current return path is required. This can be either by using the HVDC electrodes and ground, or the second line respectively. All depends which component (rectifier/converter or overhead cable) requires maintenance or repair. In the case that the second line is used as a current return path, the ground electrodes are temporarily used during the conversion from bipolar to monopolar operation. Current will then flow through the earth for a short time.

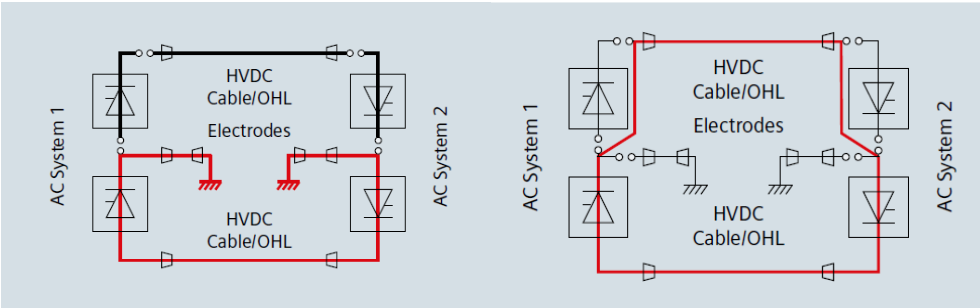

Figure 4 - bipolar HVDC system with ground electrodes (left) or dedicated metallic return cable (right)

Solar farms

Solar farms are a special case of high voltage DC system because there is only an inverter and no rectifier. High voltage DC conditions are difficult to obtain and special DC/DC converters with centralized inverter are required.. As such the solar panel systems do not transmit DC energy over long distances and do not require HVDC electrodes. However, photo-voltaic (PV) systems are grounded for fire and personal safety reasons. In the case of large PV systems significant DC leakage current may occur because the total resistance-to-ground decreases inversed proportional to the amount of PV panels. The DC leakage current flows through the ground towards the inverter grounding and may cause corrosion to pipelines buried in close proximity of the solar farm.

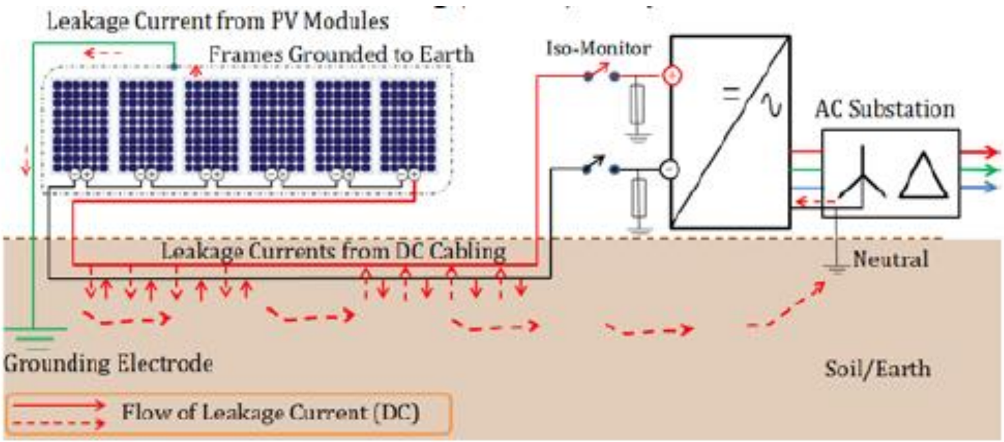

Figure 5 - DC current leak in solar systems

Solar plans are mainly found in Europe and Asia followed by North America.

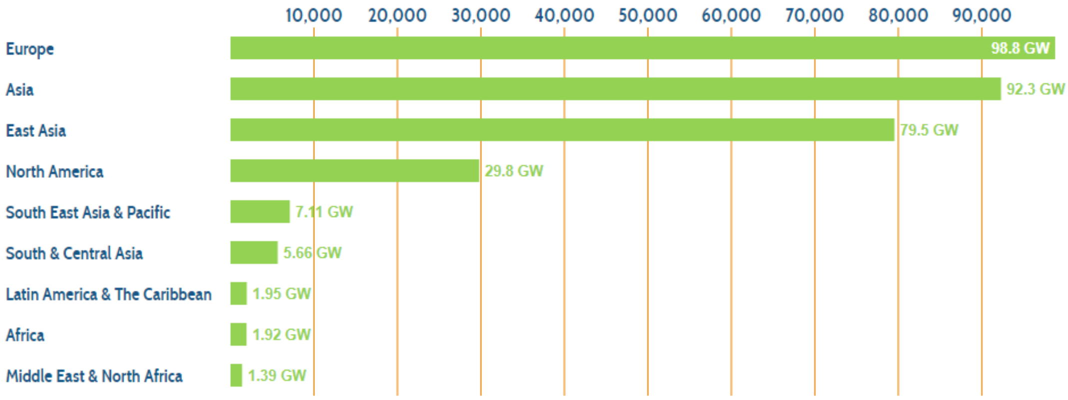

Figure 6 – overview of total power generated by operational solar farms per continent

HVDC THREATS ON BURIED PIPELINES

Corrosion and safety threats associated with HVDC lines are discussed. Corrosion threats are caused by DC stray current flowing through the ground via the HVDC ground electrodes. Safety risks occur during a fault event in the HVDC circuit causing a transient AC signal on the energized lines.

DC stray current corrosion threats

Current sense in a monopolar system is always from the rectifier to the inverter. Therefore, the electrode that injects current into the earth (anode) and the electrode that collects current from the earth (cathode) are pre-defined. However, some HVDC systems can inverse the polarity. In the case of a ground return, the ground electrode of the rectifier acts as a cathode (or negative electrode) picking up the HVDC current. At the inverter the current is injected into the earth and the ground electrode acts as an anode (or positive electrode). The current flowing through the rectifier and inverter electrode causes a ground potential rise (GPR) in the surroundings. A pipeline will pick-up or discharge current when the potential of the adjacent soil differs from the polarized pipe potential. Since the GPR around the HVDC electrode expands over large distances, the pipeline experiences potential gradients along its route and current is exchanged between anodic and cathodic sections. As a result a DC stray current is exchanged between the pipeline and the HVDC electrode which can be either a current pick-up (overprotection) or discharge (corrosion). The largest corrosion is expected near the inverter. In the case of monopolar systems with ground return, the full current load flows into the ground. In the case of a bipolar system without DMR an unbalanced current flows to the ground under normal operation which is typically 1-2% for the newer systems but can go up till 7% of the rated current for older bipolar systems. In the case a bipolar system goes into maintenance, half of the rated current flows into the ground.

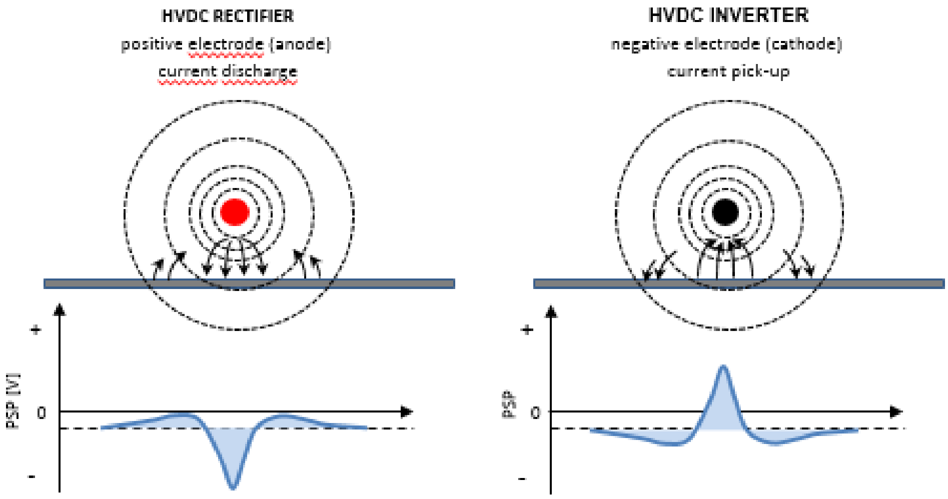

Figure 7 – principle of DC stray current interference by HVDC system on buried pipeline

A first estimation of the risk for DC interference is obtained by calculating the electric field and ground potential rise at the location of the pipeline. The electric field or voltage gradient (ε) around the electrode and the ground potential rise (V) at any distance from the HVDC electrode is calculates as:

$$\varepsilon = \frac{\rho I}{2\pi r^2} \qquad [V/m]$$

Equation 1

$$V = \frac{\rho I}{2\pi r} \qquad [V]$$

Equation 2

where:

ρ: apparent resistivity of the soil at distance r [Ωm]
I: ground current of HVDC [A]
r: distance from the HVDC electrode [m]

It must be noted that at a typical distance of 10 km from the HVDC electrodes the soil potential and electric field are below 10 V and 6 mV/m per 1000 A of ground return current respectively. Also, important to notice is that the electric field might be very high while the ground potential rise is low, and vice versa. As pipeline potential will respond to a change in ground potential, the latter is more important than the voltage gradient in the soil.
From the calculated ground potential rise at pipeline, the ON and IR-free potential and current density is calculated according to the formula.

$$E_{on} = E_{re} - U_{GPR} = \eta * J_b + R_c * J_c + E_{native}$$

Equation 3

where

Eon: pipe-to-soil potential with reference cell above pipe
Ere: pipe-to-soil potential with reference cell at remote earth
U_{GPR}: soil potential or ground potential rise at pipeline
η: polarization resistance of steel [Ωm^2]
J_b: current density at coating defect [A/m^2]
R_c: coating resistance [Ωm^2]
J_c: CP current density of the pipeline [A/m^2]

E_{native}: native pipe to soil potential

<u>Protection criteria</u>
The European Committee for Electrotechnical Standardization EN50162 and Chinese National Standard GB/T 21447-2008 state that:

1) Protective measures must be applied if the pipe leakage current density is more than 1 $\mu A/cm^2$ ($10 mA/m^2$) or the cumulative corrosion amount (thickness) affects the safe operation;
2) DC interference exists if the pipe-to-soil potential (polarization potential) is higher than 20 mV positive shift to the pipe natural potential (galvanic series potential) or the DC soil potential gradient near the pipe is greater than 0.5 mV/m. When the pipe-to-soil potential is higher than 100 mV positive shift to the pipe natural potential (galvanic series potential), protective measures must be applied;
3) For a new pipeline, if a pipeline route is in the zones where the DC soil potential gradient is greater than 2.5 mV/m, the pipeline may be subject to DC interference and therefore must be evaluated. Protective measures must be applied to mitigate the excessive DC voltages and currents.

The criteria for unprotected steel and cast-iron pipelines is based on maximum voltage shift that was determined from field experience and different practices in several countries. Annex C (informative) makes the correlation with the current density. For the case of a 200 and 15Ωm soil the anodic current density of 1 cm^2 coating defect results in an anodic current density of 42 and 37 mA/m^2 respectively. In other words, a corrosion rate of approximately 40 μm/yr.

Resistivity of the electrolyte [Ωm]	Maximum positive shift ΔU [mV] (including IR-drop)	Maximum positive shift ΔU [mV] (excluding IR-drop)
≥200	300	20
15 to 200	1.5*ρ	20
<15	20	20

Table 2 - summary of DC stray current criteria

Mitigating stray current corrosion can be achieved in the following ways:

1. applying CP current where interfering current is discharged from the pipeline. The driving voltage of the CP current source should be larger than the driving voltage of the stray current;
2. installing a grounding cell consisting of sacrificial magnesium or zinc anodes;
3. relocation of CP anode beds;
4. rerouting of proposed pipeline;
5. properly located isolating fittings (IJ) with caution that the stray current does not discharge across the isolation fitting because of the large voltage drop across it;
6. application of external coating to the current pick-up areas on the affected structure. Anodic discharge areas should not be recoated.;

An example of a mitigation system configuration for HVDC stray current is shown in Figure 8. The operator installed at the most vulnerable location a unidirectional drainage point with a diode connected between the pipeline and magnesium anodes for securing the current discharge back to the HVDC electrode. In addition, two automatic potential-controlled rectifiers with anode beds (80V/30A each) were installed on both sides of the drainage point.

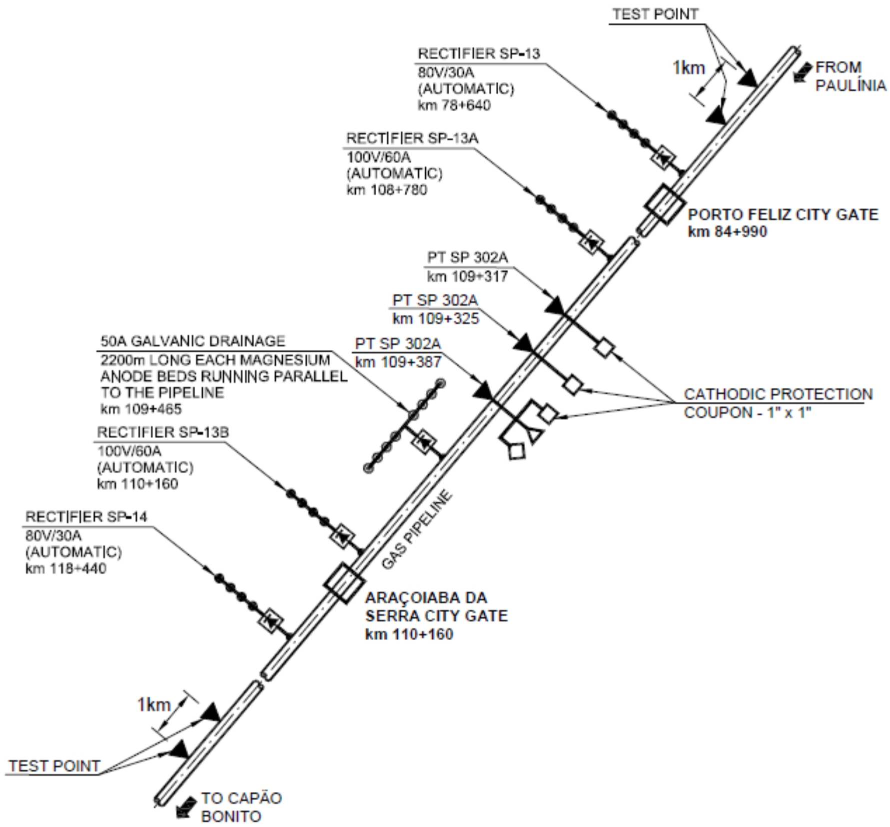

Figure 8 - example of corrosion mitigation system against stray current interference from HVDC

Case study

Numerical modeling have been performed in Elsyca CatPro for various conditions of coating defect size and soil resistivity. The simulated current density at the coating defect is plotted against the ground potential rise for the case that only the HVDC interference is applicable (no CP). Note that a current density J_b of 1 A/m^2 corresponds to a corrosion rate of 0.86 mm/yr. Figure 9 shows that the current density J_b increases with increasing soil resistivity and coating resistance. In the case that the GPR at the pipeline level is -4 V the expected corrosion current density varies between 0.5 to 9 A/m^2 for this case. For more negative GPR values the corrosion current density is higher and reaches 25 A/m^2 for a well-coated pipeline (with pinholes) in a 100 Ωm resistivity soil. For the lower interference levels, the GRP is 90 mV more electro negative than the native potential which results in a corrosion rate of approx. 50 microns/yr for a well-coated pipeline.

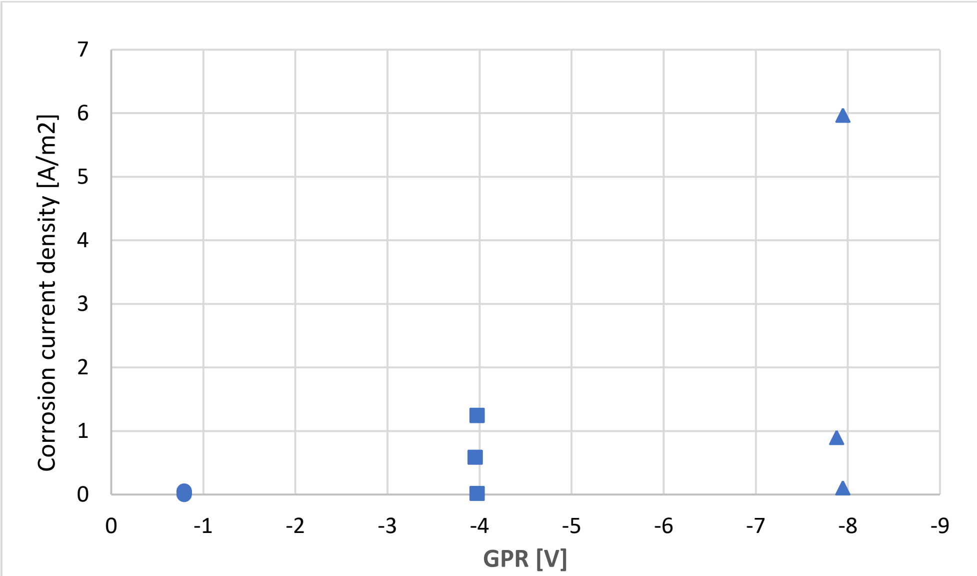

Figure 9 - simulated corrosion current density as function of GPR for different P/L coating resistance and soil resistivity (circle: 10Ωm; square: 50Ωm; triangle:100Ωm)

As an example the risk of HVDC interference was simulated for a bipolar system with the inverter electrode at approximately 20 miles from the 24" FBE coated pipeline. A global soil resistivity of 500Ωm (for the surface/top layer) and a second soil resistivity layer from 164 ft (50 m depth) of 5500 Ωcm was considered. As a result of a 1375A ground current during monopolar operation the simulated GPR and electric field at pipeline level was -12.54V and 0.86 mV/m respectively.

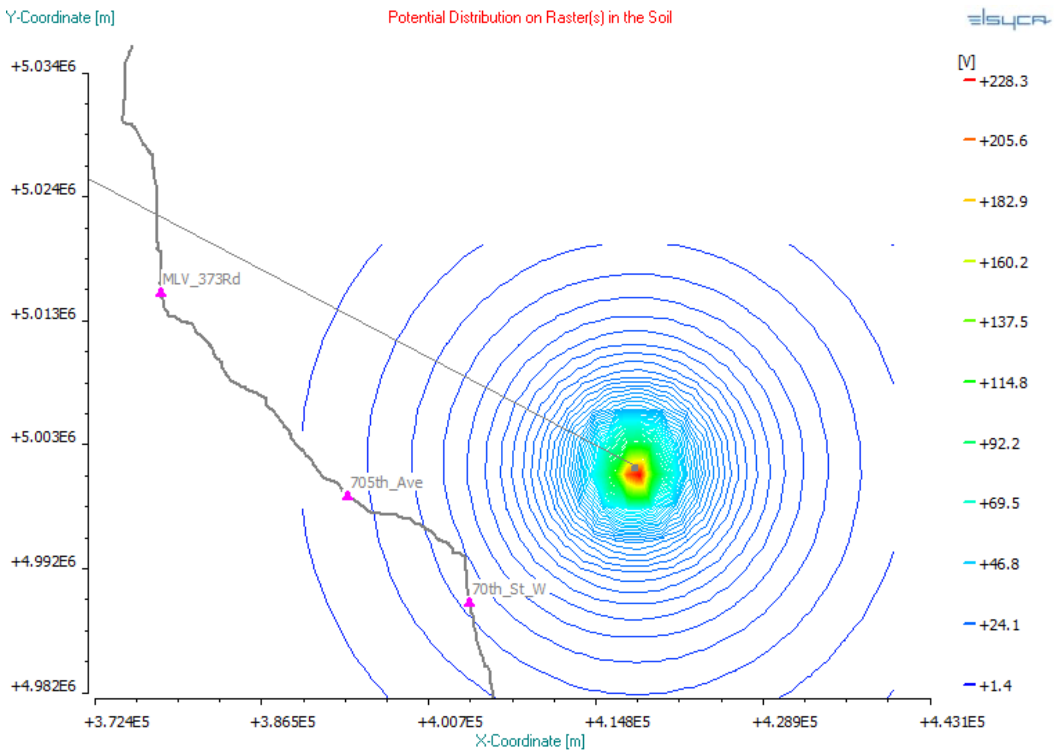

Figure 10 - simulated ground potential rise around an inverter HVDC electrode

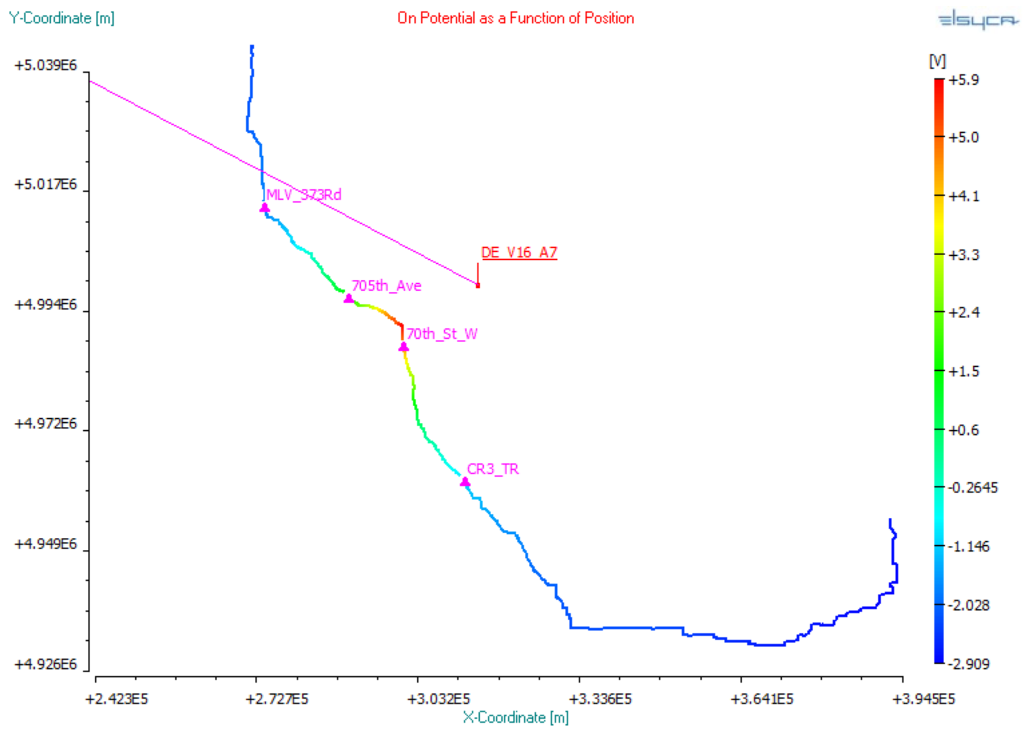

Figure 11 - simulated ON potentials on pipeline

Mitigation could be achieved with a voltage-controlled rectifier feeding a deep anode ground bed (50 to 100 m depth) having a resistance-to-earth of 2.74 Ω. The negative of the voltage rectifier should be at least more negative than the GRP of -12.54 V in order to be effective. Through iteration a voltage-controlled rectifier system of 50V/40A was recommended.

Pipeline safety risks during HVDC fault

As any electrical system, an HVDC may fault at occasions but the fault pattern is somewhat different than in faulted HVAC systems. The clearance time of HVDC systems is typically smaller than its counterpart and the wave pattern is rather a transient signal as shown in Figure 12.

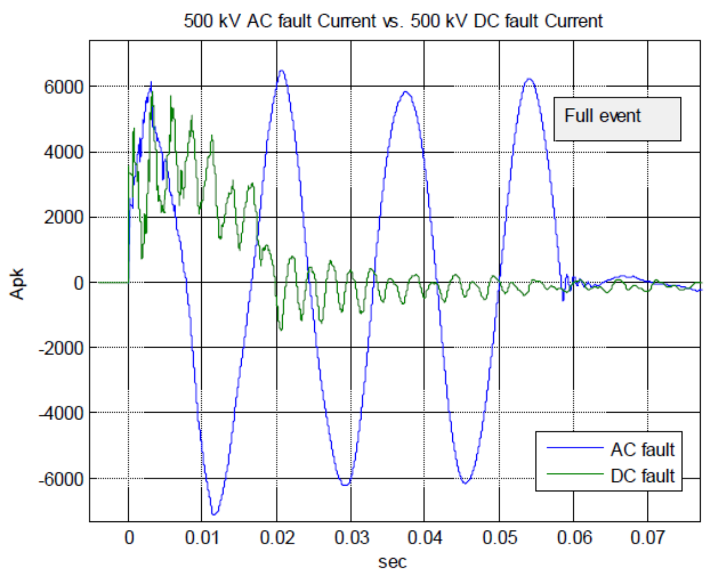

Figure 12 - comparison of typical fault current pattern between high voltage AC and DC system

During a fault event the DC current is in general not higher than 3 times the rated current. It must be noted that only the rectifier supplies the fault current and that the magnitude and duration of the DC event depends on distance between the faulted tower and the rectifier.
It will take circa 30 minutes to detect a fault of bipolar HVDC system with ground return. During this time part of the fault current will flow from the positive pole to ground. The negative pole continues to operate using ground as a return. In the case of a DMR, the current return occurs through the dedicated metallic conductor. The current flowing to the ground will be limited since the DMR and the negative pole forms parallel circuit and will both return the current to the rectifier.
There are basically two types of fault events that can occur on the HVDC line.

1. Back flashover (BF) - Any stroke to the tower top/shield wires will lead to a back flashover over the insulator if the potential difference across the insulator exceeds its critical flashover value. The conductor sits at its normal voltage potential relative to earth, whereas the tower top voltage (insulator base) is raised to very high voltage due to the lightning discharge.

2. Shielding Failure (SF) – The shield wires are designed to intercept all lightning strokes to the line but low intensity lightning strokes can evade the shield wires and terminate on the pole conductors. The consequent voltage rise can lead to insulator flashover.

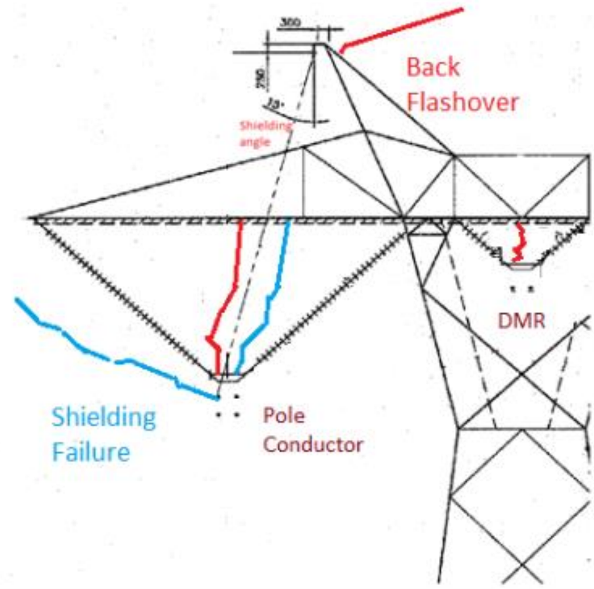

Figure 13 – type of fault modes in HVDC towers

Numerical modeling was used to determine the safe distance between pipeline and faulted power line of an HVDC system. A steel pipe enters at a straight angle the ROW of a bipolar HVDC power line, runs parallel with it for about 50 km and then diverges at straight angle. A characteristic impedance of 17 ohm is applied to each end of the pipeline to foresee electrical continuity of the pipeline. Three levels of the coating resistance are considered for simulations: 1.8, 4.8, and 22.5 kΩm^2. The clearance distance between the powerline and the pipeline is set to 30, 50 or 100 m respectively.
Fault events may cause coating stress issues and touch potential safety risks. In Figure 14 and Figure 15 the overall maximum peak voltage induced in a pipeline during a back-flashover fault event is plotted as a function of the separation distance between the pipe and the HVDC line for different coating resistances and 50 km of parallelism. The threshold values for coating stress voltage according to the Canadian Association of Petroleum Producers are shown as well. It should be noted that the induced voltage increases with the length of parallelism.

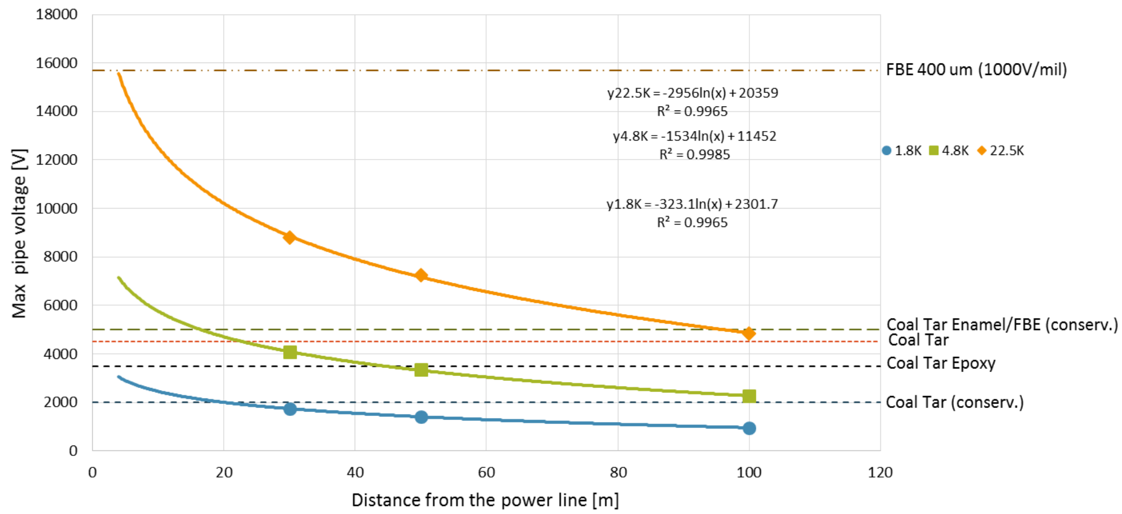

Figure 14 – total pipe voltage as a function of the distance between the pipe and HVDC line – back flashover

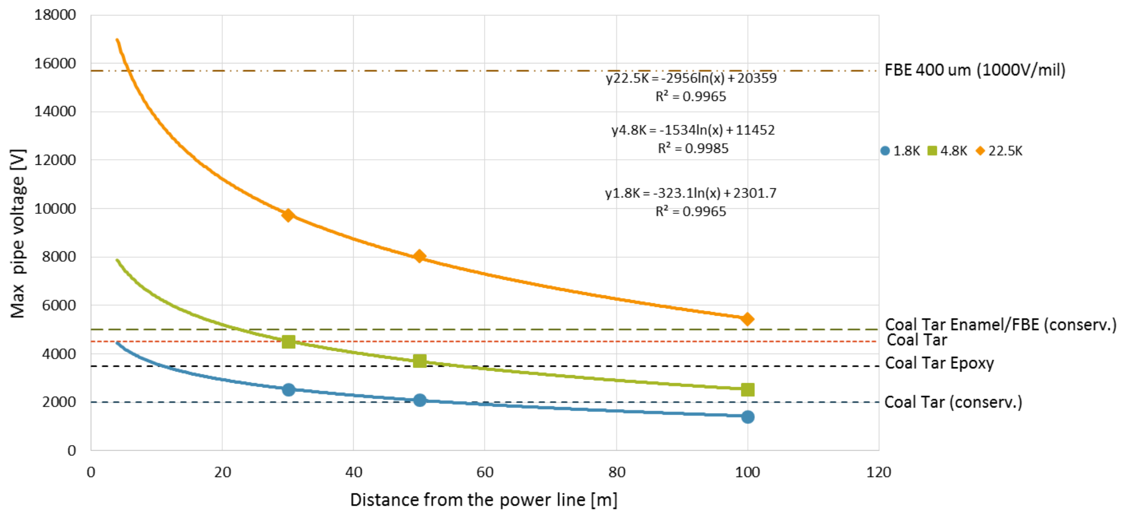

Figure 15 – total pipe voltage as a function of the distance between the pipe and HVDC line – shielding failure

Back-flashover fault results in a higher inductive component and lower resistive component of the induced voltage compared to the shielding failure.

Case of bipolar HVDC with DMR

Current transients of negative, positive poles and DMR of a bipolar HVDC during a fault event were simulated using EMTP-RV software as shown in Figure 16. These currents were used as an input for Elsyca IRIS simulations. A tower halfway the parallelism was faulted. The pipeline had a 9 kΩm^2 coating and is 30 m away from the power line.

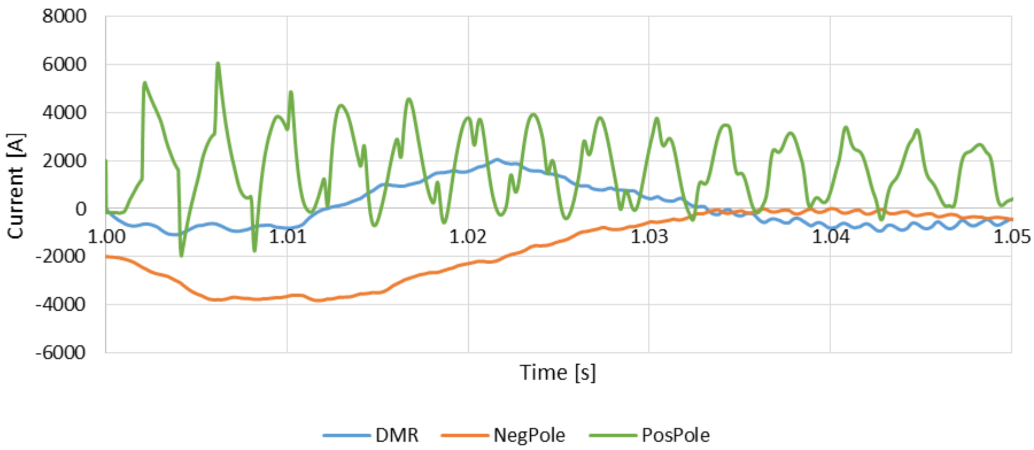

Figure 16 - currents in positive and negative poles and DMR of a bipolar HVDC system during a fault event

The simulated transient of the pipe coating stress voltage near the faulted is shown in Figure 17.

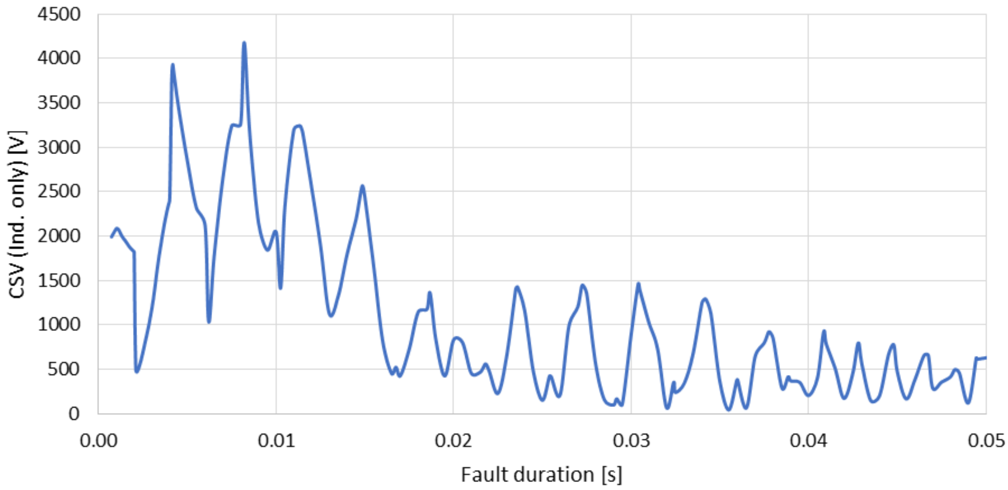

Figure 17 - coating stress voltage transient simulated for a bipolar HVDC with DMR

From the induced pipeline voltage, the shock current waveform IB (t) = V (t)/RB was calculated assuming the feet-to-hand current path (RB = 450 Ω). Figure 18 shows the induced body current at the hypothetical appurtenance together with the transferred energy normalized to the maximum value.

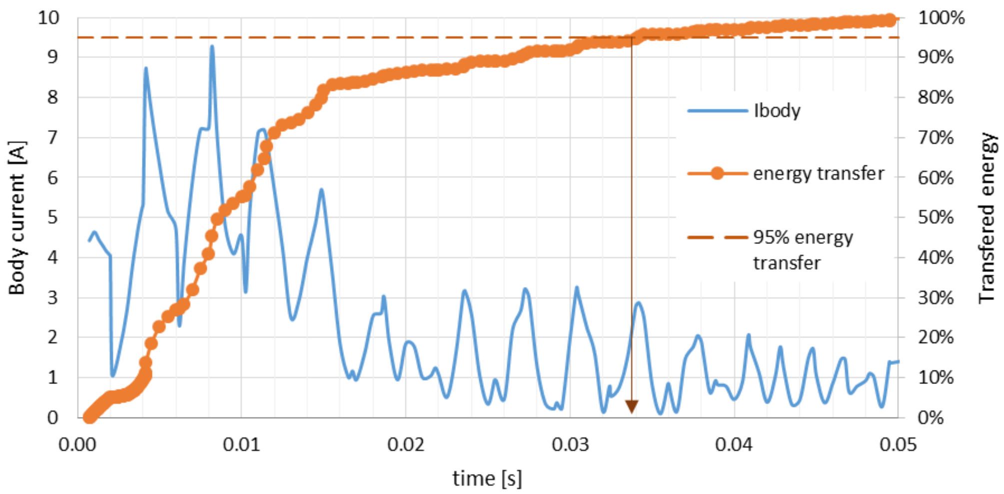

Figure 18 - shock current (I_{body}) waveform and transferred energy during a fault event on a bipolar HVDC with DMR

The duration of the event is defined as the shortest time interval of the event waveform that contains 95% of the energy over the total duration of the event waveform. In our case, the event duration is 34 msec.

The RMS value of the event waveform can be calculated for the decay duration defined above, and after application of the heart-current factor F..

$$I_{crms} = \sqrt{\int_0^T \frac{1}{T} i_b^2\,(t)dt}$$

Equation 4

where T is the fault event duration [sec].

The tolerable body limits (safe rms values of the shock current) are derived per IEEE-80 Standard [5, p.143] for 50 kg and 70 kg body weight respectively:

$$I_{B,50} = \frac{0.116}{\sqrt{t_s}}$$

Equation 5

$$I_{B,70} = \frac{0.157}{\sqrt{t_s}}$$

Equation 6

Any high initial current (within 4 msec) needs to be considered prior to the biphasic oscillations as per IEC 60479-2. The approach is to calculate the specific fibrillation charge, F_q, which is defined with the following limit conditions:

$$F_q = I_{crms,T} \times \Delta T$$

Equation 7

where ΔT = 0.004 sec.

Event waveform duration [ms]	Total event current [A_{rms}]		Path/Heart current factor	Specific fibrillation charge (4 ms) [mC]	
	Calculated	Safe limit		Calculated	Safe limit
34	3.70	0.629	Hand-to-feet, F = 1.0	25.5	2.00

Table 3 – Characteristic parameters calculated for a fault event on a bipolar HVDC system with DMR

Case of bipolar without DMR

Current transients of negative and positive poles during a fault event on a bipolar HVDC without DMR were simulated using EMTP-RV software as shown in Figure 19. These currents were used as an input for Elsyca IRIS simulations.

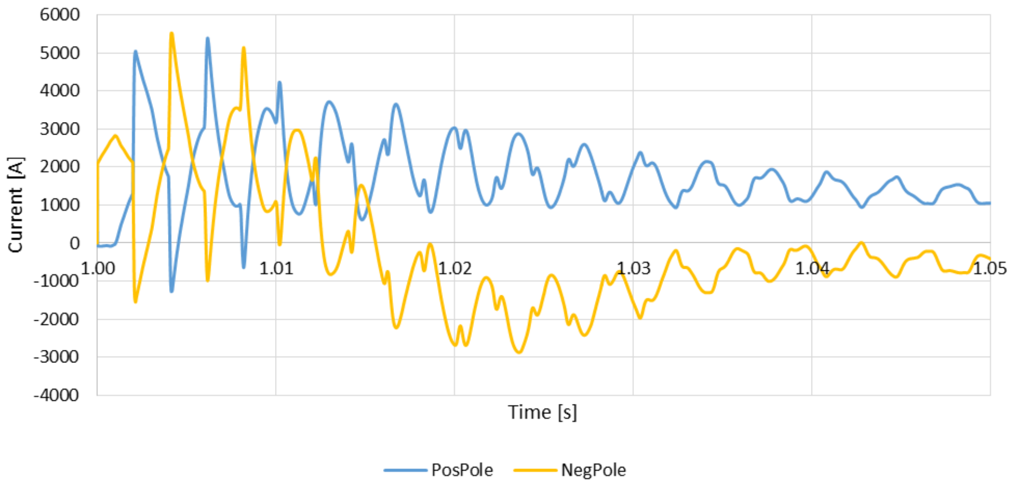

Figure 19 - currents in positive and negative poles of a bipolar HVDC system without DMR during a fault event

Maximum coating stress voltage (CSVmax) on the pipeline and CSV at the closest to the faulted tower hypothetical appurtenance (CSVP27) is shown in Figure 20. It can be seen that the induced voltage on the pipe is higher than for the HVDC with DMR.

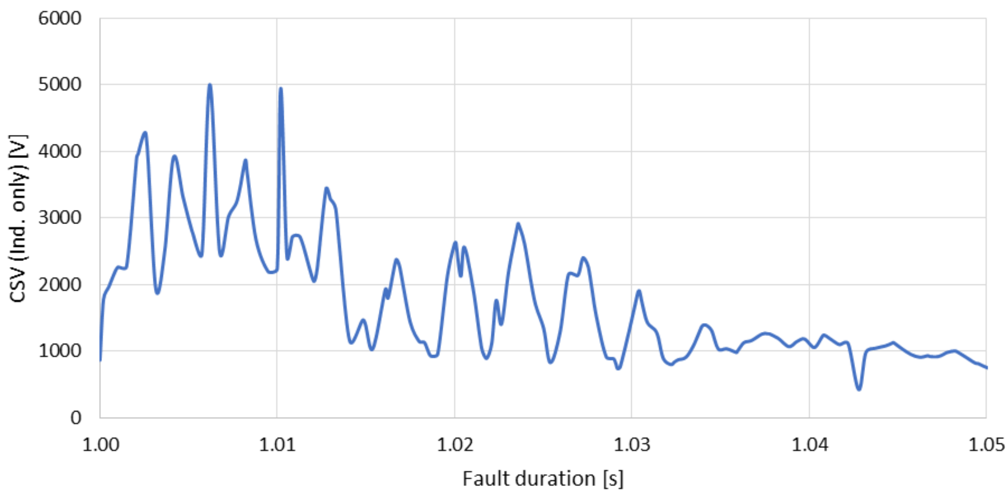

Figure 20 – coating stress voltage transient simulated for a bipolar HVDC without DMR

From the induced pipeline voltage, the shock current waveform I_B (t) = V (t)/R_B was calculated assuming the feet-to-hand current path (R_B = 450 Ω). Figure below shows the induced body current at the hypothetical appurtenance together with the transferred energy normalized to the maximum value.

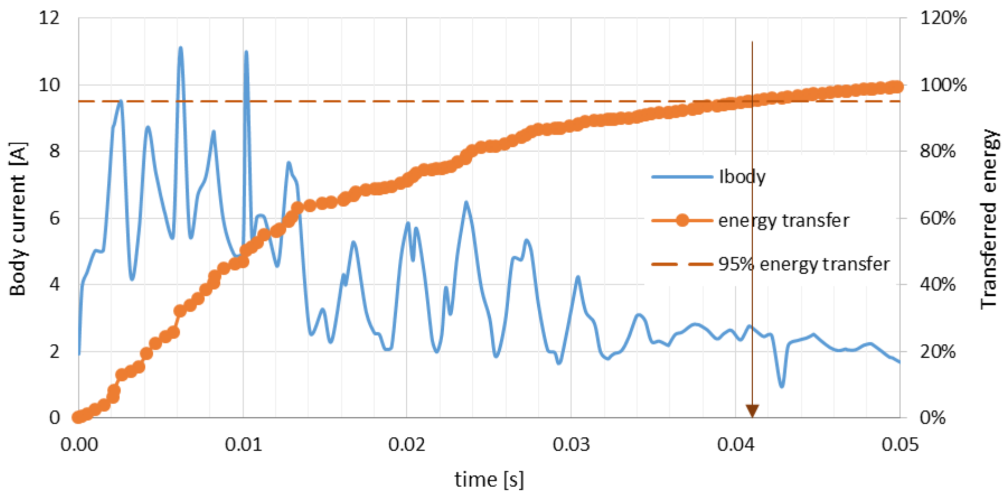

Figure 21 - shock current (I_{body}) waveform and transferred energy during a fault event on a bipolar HVDC without DMR

The event calculations performed are summarized in Table 4.

Event waveform duration [ms]	Total event current [A_{rms}]		Path/Heart current factor	Specific fibrillation charge (4 ms) [mC]	
	Calculated	Safe limit		Calculated	Safe limit
40.8	4.81	0.574	Hand-to-feet, F = 1.0	34.6	2.00

Table 4 - characteristic parameters calculated for a fault event on a bipolar HVDC system without DMR

From comparison of the data, one can conclude that a fault event on a bipolar HVDC system without DMR compared to the one with DMR:

- has a longer duration;
- results in a higher coating stress voltages induced on the pipe;
- results in a higher safety danger in terms of total event current and specific fibrillation charge.

HVDC INTERFERENCE RISK ASSESSMENT

Data gathering and system identification

The following data should be collected from the HVDC and pipeline system:

- Type of HVDC system:
  - monopolar and bipolar with ground return
  - bipolar system with DMR (for fault interference only)
- HVDC electrode system (at inverter):
  - Type: (double) ring, horizontal linear, vertical linear
  - Ground current under steady-state (full rating or unbalancing) and maintenance conditions. Negative value for cathodic current entering the HVDC inverter electrode
  - Apparent soil resistivity (Schlumberger method) till depth equals dimension of the electrode
- Pipeline:
  - Coating resistance (or coating conductance according to NACE TM0102)
  - Pipeline diameter
  - Steel specific resistivity (according NACE TM0102)
  - Distance from HVDC inverter electrode
  - Soil resistivity along the pipeline routing

- CP survey data

Risk assessment procedure

Corrosion risk

The following parameters should be calculated for the HVDC electrode

- Resistance-to-earth of the electrode system with eq. 1 to 3taking into account the local soil resistivity around the HVDC electrode and its dimensions.
- Soil potential rise at the electrode:
  - Vre = Re*I
- Ground potential rise at pipeline level at given distance from the HVDC electrode by dividing Vre with the distance r between the HVDC electrode and the pipeline. Value can be adjusted in function of the deeper soil layer resistivity values.
- Electric field or voltage gradient at pipeline level by dividing ground potential rise by distance r from the HVDC electrode

The evaluation of the potential risk is then as follows:

- Voltage difference V between the PSP (remote earth) and ground potential rise in absolute value:
  - High risk if V > 4
  - Medium risk if 1V < V< 4V.
  - Low risk if V<1V
- Electric field or voltage gradient ε:
  - High risk if ε>0.3mV/m
  - Medium risk if 0.1< ε <0.3mV/m
  - Low risk if ε <0.1mV/m

Note that the ground potential rise is more important than the electrical field or voltage gradient and that the risk increases with coating resistance and soil resistivity and decreases with increasing coating defect size.

It is recommended to install IR drop probes for line current measurement and test stations for potential readings at the pipeline section that is nearest to the HVDC electrode. Coupons and ER probes must be installed to measure current density and corrosion rates.

Mitigating DC stray current interference is successful if voltage-controlled rectifiers are used at the pipeline section nearest to the HVDC electrode. The voltage rating must be sufficient to bring the pipe potential more electro negative than the ground potential rise caused by the HVDC electrode, and to compensate for the voltage drop over the anode bed and the soil. The current rating must be at least twice that of the change in line current caused by the stray current. Grounding materials connected to the pipeline are less effective in mitigating the DC stray current. The resistance-to-earth should be much smaller than that of the pipeline. In any case groundings can drain off only a fraction of the DC stray current that is picked up by the pipeline.

Verify if HVDC overhead power line towers are in close proximity with the pipeline. Crossings are of lesser concern since the ground potential rise is not sufficient due to limited fault current (approx. 6000A max) of HVDC lines. However, in the case of long parallelism (> 50km) between the HVDC line and the pipeline, safety issues exists. The drainage current that flows to a human must be computed from the induced voltage and the transferred energy during the fault event must be compared with tolerable limits according to IEEE-80.

Safety risk

For the safety risks the following powerline characteristics should be requested for the line that parallels the pipeline:

- HVDC system
  - Type of HVDC system including absence/presence of DMR

- Profile of the fault current transient
    - Location of the rectifier
    - Tower resistance to earth
    - Length of parallelism
- Pipeline system: same as for corrosion risk

CONCLUSIONS

HVDC systems may cause corrosion and safety risks on pipelines. From a DC stray current corrosion perspective distances of a few tens of kilometers near HVDC stations shall be considered for initiating corrosion assessments. Pipeline operators should consider a maximum ground potential rise of 4V near the pipeline. For safety reasons a parallelism between the pipeline and HVDC powerline routes of a few tens of kilometers shall be considered. The accumulated charge in the human body must be calculated based on the duration and amplitude of the transient voltage induced in the pipeline. Corrosion and safety risk assessments must be performed through numerical modeling because most often the threats occur unexpected and are thus impossible to measure in the field.