Study Committee C4

Power system technical performance

Paper ID_10926

DC Power Quality assessment on real MVDC and LVDC power systems

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Motivation

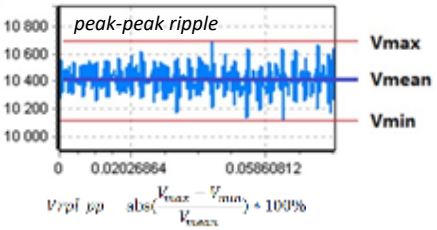
If zooming a DC voltage or current waveform of a power electronic converter, we can observe often some AC undulations: here appear DC power quality (PQ) issues

Several actual DC projects have been recently committed in the world, but relevant DC PQ standards are almost absent or insufficient.

Now, DC PQ issues should be considered to support the fast development of DC power distribution grids and the equipment suppliers, and to create new DC electromagnetic compatibility (EMC) environment.

Method/Approach

- Collect on-site DC PQ issues and study all possible DC PQ index based on AC PQ knowledge and experience.
- Recommend DC power quality measurement methods and PQ indices computation algorithms.
- Define PQ frequency ranges adapted from existing measurement standards.
- Study DC PQ simulation methods, integration of PQ indices in grid simulation tool and assess DC power supply capacity for PQ propagation studies.



Objects of future application

- First start with on-site recordings to explain the actual observations with studied PQ indices.
- Study the feasibility of DC PQ computation in present measurement devices with minimal adaptation.
- Analyze DC PQ levels of several real MV&LVDC projects and compute actual DC PQ indices.
- Assess converter-based DC power supply capacity in terms of PQ behaviours.
- Methods of simulation of PQ in DC distribution grids.
- Recommendation of DC PQ indices and prepare future standardization topics.

Experimental setup & test results

- Actual DC PQ levels from laboratory tests of LVDC devices and on-site measurements of several MV and LV DC projects.
- Waveform recordings and DFT analysis up to 500 kHz. R.m.s. values are integrated in various durations.
- Study of steady-state DC power quality indices and values such as DC ripple and ripple distortion.
- DC PQ issues are different compared to that of AC such as type of DFT windows: recommendation of future works on international standardization.

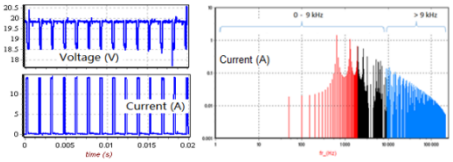
Discussion of some technical issues

- Steady state DC ripple distortion should be quantified by both peak-peak and r.m.s. values in predefined integration duration and frequency ranges.
- Integration duration may be 10ms for fast r.m.s. recording and 10min for steady state measurements.
- Recommended frequency ranges for conducted low frequency disturbance are 0-9 kHz and 9-150 kHz.

Focus on steady state DC PQ indices

For low frequency conducted disturbance assessment in DC grid, window length and frequency ranges are:

- 0 – 9 kHz range is to be quantified with IEC methods and > 9 kHz range with CISPR16 methods.
- Fast r.m.s. values are used for voltage dip, surge, peak-peak ripple min, max and mean values.
- DFT window may be 200 ms and r.m.s. integration period may be 1 min, 5 min, 10min or 15min.
- Verified with lab tests and actual on-site recordings. Here is one of the examples: DC waveforms, spectra, ripples and simulation results.



DC PQ analysis

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DC PQ modelling in f-domain solver

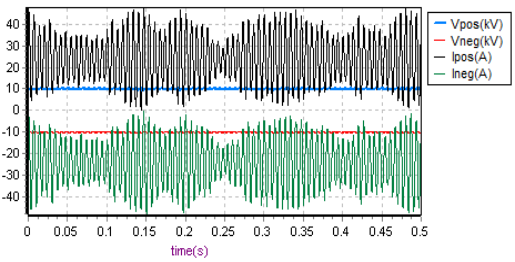
DC PQ indices may be computed with frequency domain simulation tool: a fast solution for grid PQ engineers.

- Set min frequency value to deal with DC component
- Component models (power source, transformer, line, cable, load, etc,) : avoid pure inductance branches
- Model fitting with on-site measurements
- Data processing of DC value with mean value, instead of peak value used in AC components.
- AC and DC grid simulation to assess whole grid power quality indices such as DC ripples, spectral distortion, DC unbalance, etc.

DC PQ computation of actual events

The figure below is a transient instability event captured from a MVDC project when on-site adjustment:

- Voltages and currents waveforms recorded from bipolar outputs during the transient oscillation of a bidirectional feeder.
- Post-processing in time and frequency domains and computing DC PQ indices.
- DC PQ indices show the abnormal oscillations in positive and negative poles (important peak-peak and RMS ripples).



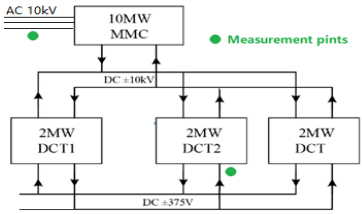
	Positive Pole A	Positive Pole V
RMS Values	26.38A	9980V
Peak-Peak Ripple	198%	12.8%
RMS Ripple	48%	2.7%

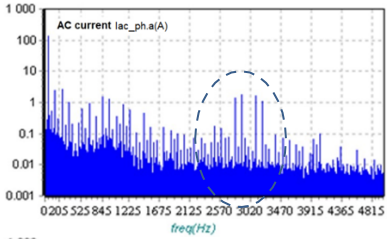
	Negative Pole A	Negative Pole V
RMS Values	26.49A	10500V
Peak-Peak Ripple	199.6%	7.91%
RMS Ripple	48%	1.27%

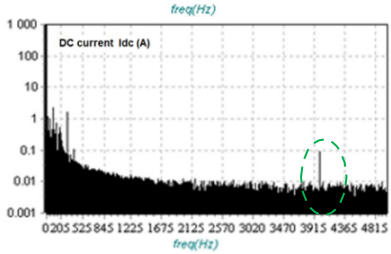
Power quality issues in AC/DC systems

Three phase AC currents of a PWM AC/DC converter station of a 10 MVA LVDC EV charge systems and DC voltage and current of one converter are recorded and analyzed.

AC current includes spectra around 3 kHz results due to the AC/DC converters and 4kHz in DC current.







Conclusion

- Recommended DC PQ indices could be integrated into common grid PQ measurement devices and power quality simulation tools
- Recommended DC spectral analysis frequency ranges are in line with existing AC relevant standards
- The proposed adaptation and development within a general AC PQ simulation software enable to study easily grid DC PQ under f-domain computation.
- Evaluation of converter-based DC power supply capacity is an important step to assess PQ issues in DC distribution network.

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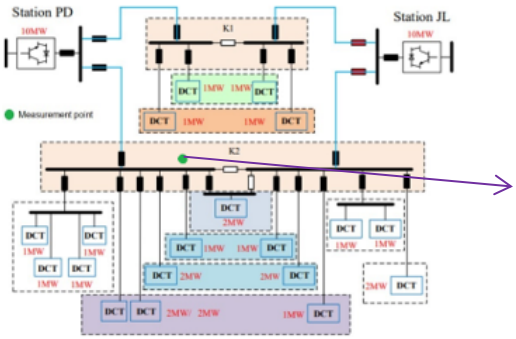
(continued for additional events)

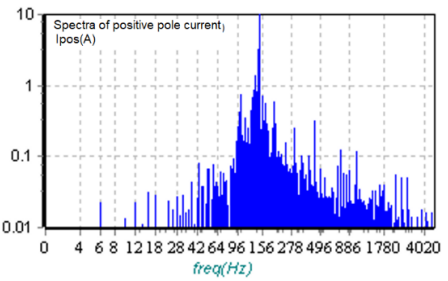
Actual DC PQ issues observed

Temporary oscillation occurred in actual 20 MW bipolar MVDC and LVDC project (MVDC at +/-10kV, LVDC at +/-375V) and analyzed under time and frequency domains.



Analysis of DC ripple spectra

- Bipolar current measured on +/-10kV feeder : spectral analysis during the transient oscillation: main oscillation frequency is around 150 Hz with several side band spectra.
- Max r.m.s. spectrum reaches 10A under 10kV.

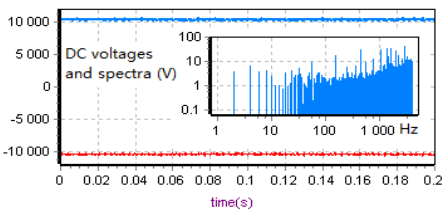


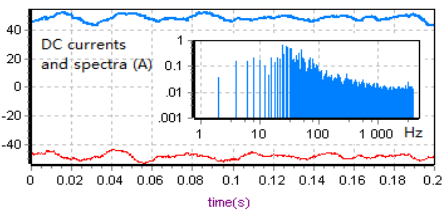
Bipolar DC project: cause of DC PQ

- Recordings of voltage and current of 2 poles: existence of a DC voltage undulation due to DC load current fluctuation and DC power supply converter.
- Seek the source of DC PQ issues by f-domain simulation based on actual measurements.

Computing DC power quality indices

- From spectral analysis, it is recognized that voltage spectra > 100 Hz is not caused by the load current variation but residual spectra of the AC/DC converter.
- Simulation results based on real recordings show that ripples of DC bus voltage are 5.78% (peak-peak) and 0.919% (r.m.s.).





Simulation of DC PQ indices based on the on-site measurements: