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DC SYSTEMS & POWER ELECTRONICS

11089

Online Estimation of Dynamic Capacity of VSC-HVDC Systems – Proof of Concept in NordLink

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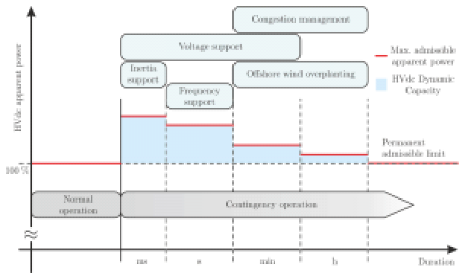

Figure 1: Power system use cases for dynamic capacity of VSC-HVDC systems.

Motivation

- Efficient use of equipment in transmission system is becoming increasingly important because delays in grid expansion projects can restrain the integration of renewables.
- Temporary increased utilization of the asset beyond guaranteed active and reactive power limitations is of great interest in modern power system operation (Fig. 1).
- Proof of concept investigates inherent temporary overload (dynamic capacity) for VSC-HVDC stations (Fig. 2)

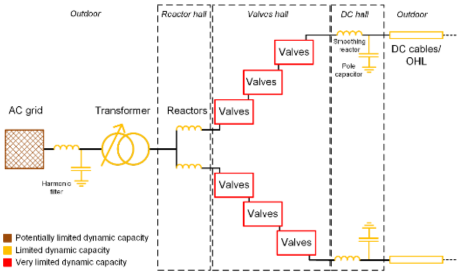

Figure 2: Overview of VSC-HVDC station components and qualitative assessment of their dynamic capacity.

Method/Approach

- Field data from German NordLink HVDC Light converter station was used.
- Operational data has been utilized in combination with design knowledge for the development of the dynamic capacity system model.
- Dynamic capacity system model is compiled in a software prototype to which either historic (offline) data, forecast data or live data on premise can be fed
- Outputs could be visualized online at the site or offline.

Objects of investigation&results

- German NordLink HVDC Light converter station was used for proof-of-concept
- Out of scope of this work have been the DC line and AC grid dynamic capacity. Also, for active power the other terminals' capabilities need to be respected.
- It is not planned to actually apply dynamic capacity at this link.
- Dynamic capacity of active power is estimated to be 14.0% and 26.9% higher than the guaranteed limit when considering full guaranteed reactive power range for two selected summer and winter days in 2021 (see further results on page 2).

Conclusion

- **HVDC Light stations** may possess dynamic capacity beyond their guaranteed limits
- **Proof-of-concept** is based on measurement data that has been collected from the German **NordLink converter station** since March 2021
- **Main influencing factors** are the **outdoor ambient temperature** and **PCC voltage** (for 30 to 90 min time duration)
- Concept for integration of dynamic capacity into the **system operation process** of the grid operator
- Potential of HVDC Light for **curative congestion management** is expected to be significant

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Results: Input field data

- Data recorded since start of commercial operations in March 2021
- Software prototype was fed with historic field data from an arbitrary day in June 2021 (warm day), as well as October 2021 (cold day)
- Steady-state PCC voltage quite stable for both days, median around 407 kV (Figure 3)
- Outdoor ambient temperature << specified design value of 40°C. Warm day median 27.2°C, max 34.7 °C. Cold day median 13.3 °C, min 2.2 °C (Figure 4).

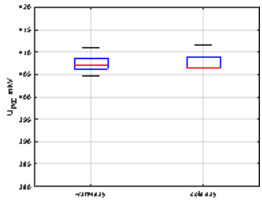

Figure 3: Boxplot PCC voltage variation for both cases.

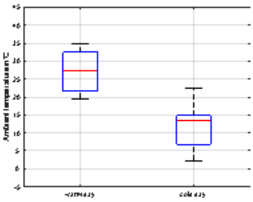

Figure 4: Boxplot outdoor ambient temperature measurements.

Results: Cold day case

- Active power dynamic capacity of the HVDC converter station available for a period of 60 minutes displayed in Fig. 6 for cold day
- Active power dynamic capacity is superior in the cold day case compared to the warm day case
- Dependency on ambient temperature is smaller for lower outdoor ambient temperatures

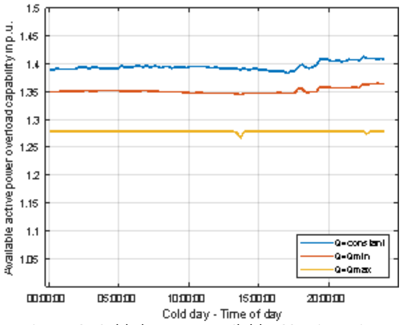

Figure 6: Cold day case available 60 min active power dynamic capacity in p.u. in dependence of reactive power set-point.

Results: Warm day case

- Active power dynamic capacity of the HVDC converter station available for a period of 60 minutes displayed in Fig. 5 for warm day
- Capacity is higher during colder night hours and lowers with the start of day (high temperature dependency)
- Utilizing less reactive power increases the active power potential

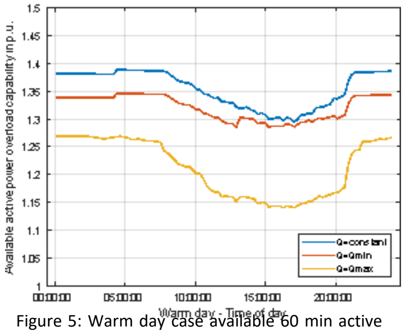

Figure 5: Warm day case available 60 min active power dynamic capacity in p.u. in dependence of reactive power set-point.

Main Results

- Daily outdoor ambient temperature variation has impact on dynamic capacity magnitude particularly in warm day case
- Available active power overload capability of 29.5% to 41.2% would be possible from the HVDC converter station (findings on Fig. 7+8)
- Full guaranteed reactive power requirement (Qmin and Qmax) would still provide a potential between 14.0% and 26.9% (findings on Fig. 7+8)

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System operation processes Preventive vs. Curative

- N-1 security is usually maintained in a preventive way (Fig. 9 a); **preventive congestion management** reduces loading of the affected transmission line in normal operation to not exceed permanent admissible transmission limits (PATL) in real N-1 case
- **Curative congestion management** allows higher loadings in normal operation (Fig. 9 b); thermal overloading of the transmission line is avoided if the loading is kept below the so-called temporary admissible transmission loading (TATL)

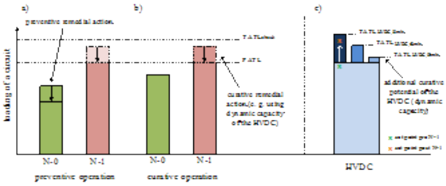

Figure 9: a) N-1 principle in preventive operation, b) N-1 in curative operation, c) dynamic capacity for curative operation.

Consideration of dynamic capacity for curative congestion management

- HVDC systems are very suitable for curative remedial actions because they can quickly adapt their set points.
- Dynamic capacity of an HVDC system means the curative potential can be increased; would reduce need for costly preventive remedial actions
- Dynamic Capacity of HVDC systems would cover 30 to 90 mins and then be substituted by other remedial actions (Fig. 10)

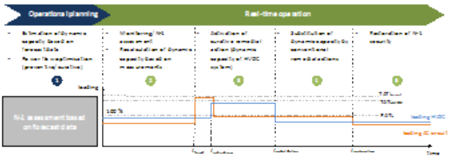

Figure 10: Consideration of dynamic capacity in system operation processes.

Conclusion

- **HVDC Light stations** may possess dynamic capacity beyond their guaranteed limits
- **Proof-of-concept** is based on measurement data that has been collected from the German **NordLink converter station** since March 2021
- **Dynamic capacity of active power** is estimated to be **14.0% and 26.9%** higher than the guaranteed limit when considering full guaranteed reactive power range
- **Main influencing factors** are the **outdoor ambient temperature** and **PCC voltage** (for 30 to 90 min time duration)
- Concept for integration of dynamic capacity into the **system operation process** of the grid operator
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Further work

- Analysis and modelling of the **lifetime impact** of this feature would be of great interest to push technology readiness level (TRL)
- **Dynamic performance studies** to be conducted and potential deviations from guaranteed performance to be assessed and agreed upon between supplier/customer
- Authors would be open to **engage with cable manufacturers** on assessing the **potential of dynamic capacity of HVDC cables and overhead lines**

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