Study Committee C4

Power system technical performance

10541_2022

An Estimation for Short-Circuit Power Changes in the Dutch Grid to Analyze the Impacts of Energy Transition on Voltage Dips

Roozbeh TORKZADEH*[1], Jeroen van WAES[2], Geert MULDER[2],
Vladimir ĆUK[1], and Sjef COBBEN[1],
[1]Eindhoven University of Technology,
[2]TenneT TSO BV,
The Netherlands.

Motivation

The energy transition is undergoing worldwide. A massive share of generation from fossil-fuel synchronous generators will be replaced with power from renewable energy sources.

A common practice is to foresee grid reinforcements and reconfigurations to enable the electricity grid for the energy transition.

An essential question that grid operators need to answer is:

"Is it possible to meet the grid code requirements after the energy transition?"

Maintaining the power quality within the existing requirements from the grid code is an example that can be derived from the question.

In this research, we investigated the residual value of the voltage dips. Severe voltage dips can cause interruptions of critical loads, resulting in process faults and high costs of industrial customers. An illustrative example is the voltage dip that caused an interruption in the operation of Schiphol International Airport, Amsterdam, the Netherlands, in 2018.

The system strength and particularly short-circuit power are anticipated to changes because of change within the grid configuration and generation shift.

The Dutch Grid Code on Voltage Dips

The Dutch electricity grid code can be named as one of the pioneers in defining limits for severe voltage dips.

The below table shows the voltage dips requirements in the Dutch grid code. The distinction between non-severe (Class A) and severe (Classes B1, B2, and C) voltage dips is majorly adopted from EN 50160 Standard that considers the operation time of protection equipment and residual voltage during the event.

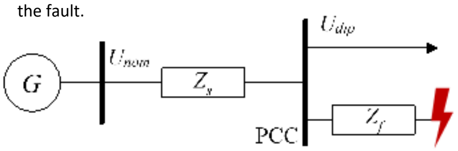
For each severe class, a limit is defined (per voltage level). These limits are based on five-year average values.

The number of voltage dips per each connected-party shall not exceed these limits.

It is also essential to investigate if these limits could be met after the energy transition.

Short-circuit Power and Voltage Dips

Residual voltage during the voltage dips for a certain node is determined by the short-circuit at the location of the fault.



$$U_{dip} = \frac{Z_f}{Z_f + Z_s} \cdot U_{nom} = \left(1 - \frac{Z_s}{Z_f + Z_s}\right) \cdot U_{nom}$$

$$Z_{sc} = \frac{U_{nom}^2}{S_{sc}}, S_{sc} = \sqrt{3} \cdot U_{nom} \cdot I_{sc}$$

"Changes in the short-circuit power can be used as an indicator to gain insight about changes in the severity of voltage dips."

The following could be considered as the change drivers:

- Generation shift from the fossil-fueled synchronous generation units (SGUs) to inverter-based renewable energy sources (IBRs).
- Grid developments and establishment of new (E)HV stations, lines, etc.
- Changes in the network configuration to avoid congestion in the HV grid.

"The increase in the system impedance and reduction in short-circuit will results in more severe voltage dips in the future."

<table>
<tr><th rowspan="2">Residual Voltage (p.u.)</th><th colspan="4">Duration (ms)</th></tr>
<tr><th>10 to 200</th><th>200 to 500</th><th>500 to 1000</th><th>1000 to 5000</th></tr>
<tr><td>0.8≤U<0.9</td><td colspan="4" rowspan="1">Class A</td></tr>
<tr><td>0.7≤U<0.8</td><td rowspan="2">Class A</td><td>Class A</td><td colspan="2" rowspan="4">Class C (MV:4/(E)HV:0.4)</td></tr>
<tr><td>0.4≤U<0.7</td><td rowspan="3">Class B2 (MV:4/(E)HV:1.2)</td></tr>
<tr><td>0.05≤U<0.4</td><td rowspan="2">Class B1 (MV:3/(E)HV:1.2)</td></tr>
<tr><td>0.01≤U<0.05</td></tr>
</table>

Study Committee C4
Power system technical performance
10541_2022

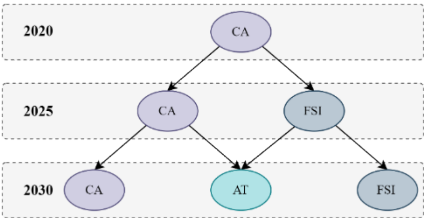
An Estimation for Short-Circuit Power Changes in the Dutch Grid to Analyze the Impacts of Energy Transition on Voltage Dips

Roozbeh TORKZADEH*[1], Jeroen van WAES[2], Geert MULDER[2],
Vladimir ĆUK[1], and Sjef COBBEN[1],
[1]Eindhoven University of Technology,
[2]TenneT TSO BV,
The Netherlands.

Scenario Selection

According to the investment plans by TenneT TSO, the transmission system operator of the Netherlands, their trajectories can happen for the energy transition in a 10-year horizon.

- Climate Agreement (CA);
- Fundamentals for System Integration (FSI);
- Alternative Transition (AT).



For each of the states above, operational scenarios for 8736 hours have been developed. We proposed three system-level indices to distinguish between each evolution path for the grid.

- Nominal Power of In-service Synchronous Generation [GW];
- Aggregated Load [GW];
- Non-synchronous Penetration Index.

$$\text{Aggregated Load} = P^{NL}_{Load} + P^{Export}_{HVDC} + P^{Import}_{HVAC}$$

$$\text{Non-Sync. Pen. Index} = \frac{P_{RES} + P^{Import}_{HVDC}}{\text{Aggregated Load}} \times 100\%$$

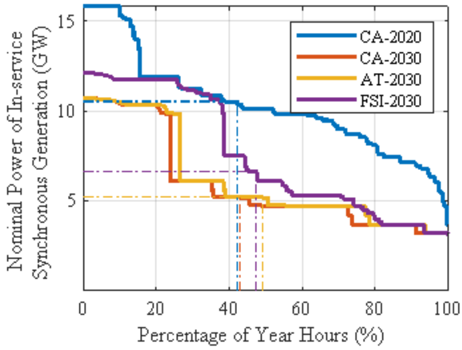
To understand the changes driven by the energy transition, two cases needed to be compared. One represents the existing situation versus the other which represents the future situation.

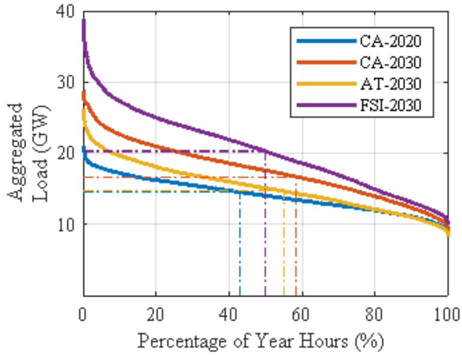
"How to select the most representative scenarios for the existing and the future grid?"

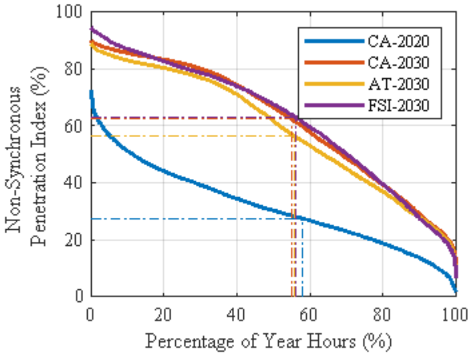
Considering the goal of this study, the most typical conditions of the grid in 2020 (existing scenario) and 2030 (the future scenario) are the best options to be compared since:

"Voltage dip is considered a random phenomenon and is expected to happen during the most typical grid states."

The values for the three introduced indices should have a typical value simultaneously for the selected typical hour. We define typicality in such a way that the value of each index must be greater than the typical value for about 50% of the times of the year and less for the rest of the year.







Study Committee C4

Power system technical performance

10541_2022

An Estimation for Short-Circuit Power Changes in the Dutch Grid to Analyze the Impacts of Energy Transition on Voltage Dips

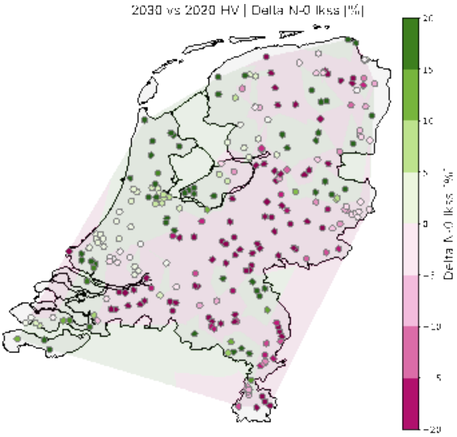
Roozbeh TORKZADEH*[1], Jeroen van WAES[2], Geert MULDER[2],
Vladimir ĆUK[1], and Sjef COBBEN[1],
[1]Eindhoven University of Technology,
[2]TenneT TSO BV,
The Netherlands.

Results and Discussions

Several comparisons between short-circuit power changes are depicted. The green color represents an increase, and the red color denotes a decrease.

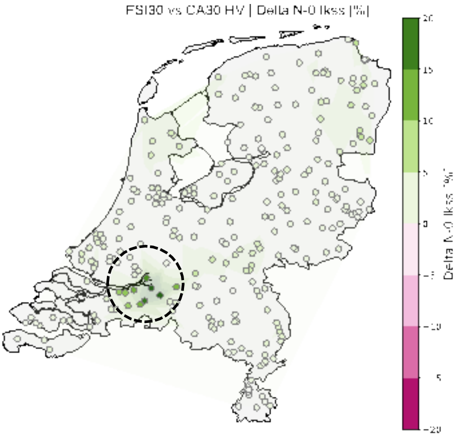
A. Combined Impact

A comparison between CA2030 vs. CA2020 shows the compound impact of all change drivers, including the generation-shift, more RES generation MV grid, grid reconfigurations, and grid reinforcements.



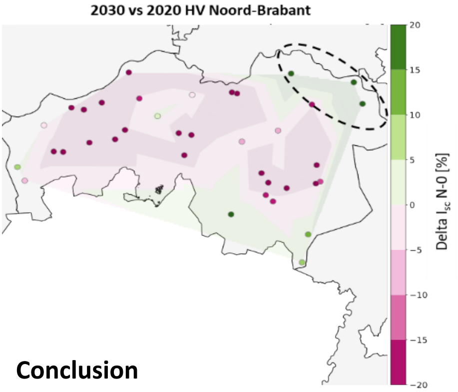
B. Impact of Generation-shift

The local impact of synchronous generations on the short-circuit power can be seen below. An extra in-service synchronous generation caused a greener area in its vicinity.



C. Impact of Grid-openings

- The nodes close to the boundaries of load pockets are the ones that will be expected to have lower short-circuit power.
- Grid opening causes a limited area of propagation.
- The increase in the northern area (depicted with a dashed circle) is due to establishing a new EHV station.



Conclusion

- Using grid openings in HV grids to prevent parallel power flow will limit the propagation area (+).
- Short-circuit power will be reduced at the node closest to the load pockets (-). It is advised that grid openings be avoided near critical nodes.
- Generation transitions toward IBRs and decommissioning or less frequent dispatch of synchronous generators will have a negative impact on short-circuit power (-).
- Compared to other changes, the generation shift demonstrate a local and limited impact.
- The nodes within load-pockets will experience more severe voltage dips compared to existing scenario.
- The total impact strongly differ per node. For the areas with new substations an improvement is very likely.