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Study Committee C6

Active Distribution Systems and Distributed Energy Resources

Paper 10683_2022

Improvement of high-speed railway power supply utilizing power electronic solutions – case studies

Philippe MAIBACH, Chuanhong ZHAO, Uzair JAVAID, Tobias THURNHERR

Hitachi Energy Ltd., Switzerland

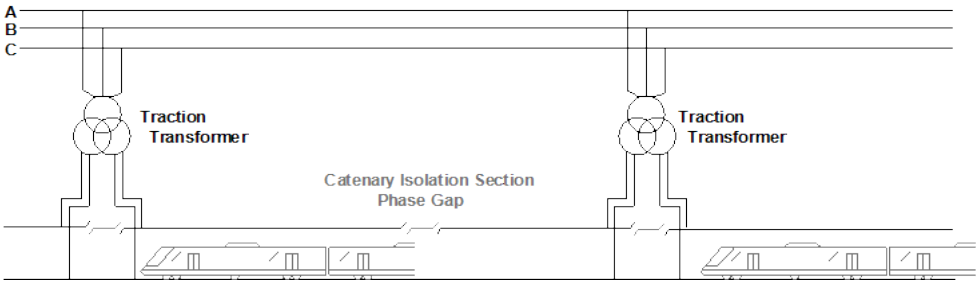
Motivation

High-speed railway systems are high-power single-phase loads to the utility grid.

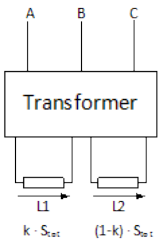
Traditionally, they are supplied by transformers from the three-phase utility grid.

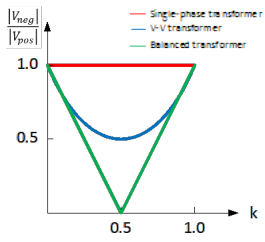
Although straight-forward, this supply concept includes a number of drawbacks:

1. 100% unbalance load – connection to HV / EHV required
2. Unbalance needs to be shared between phases
   - ➢ Railway system needs to be split by neutral sections
   - ➢ Substantial transients when a train passes a neutral section
3. Special "balancing" transformer topologies are required
   - ➢ Even so, balancing will not be ideal



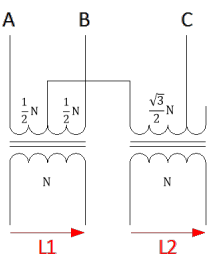
Classical solution: balancing performance

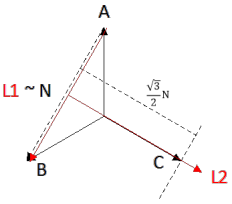




k: share of power supplied to one track section
1-k: share of power supplied to the other track section

Example: Scott transformer





N: number of winding turns

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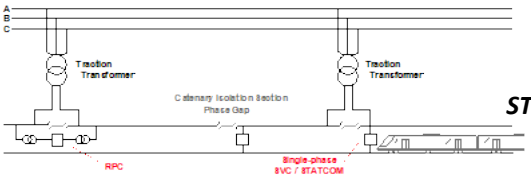
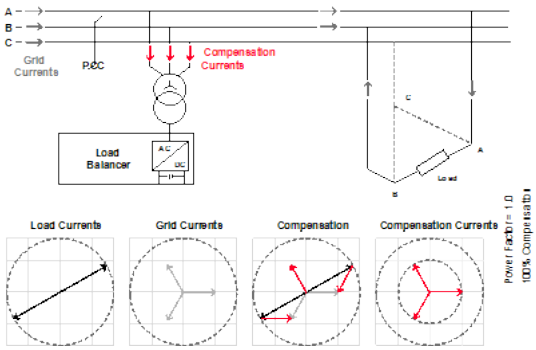
Improvement methods

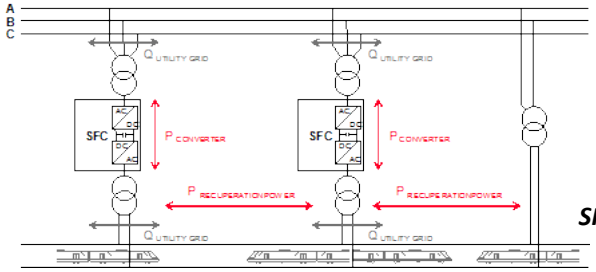
Single-phase compensation equipment



Three-phase compensation equipment



Static frequency converters



	1ph V control	1ph Q compensation	1ph harmonics mitigation	3ph harmonics mitigation	3ph p.f. improvement	Balancing	Neutral section elimination	Load sharing btw substations	Higher distance btw substations
SVC	✓	✓	✓	✗	✓	✗	✗	✗	✓
STATCOM	✓	✓	✓	✗	✓	✗	✗	✗	✓
RPC	✓	✓	✓	✗	✓	✓	✗	✗	✓
Load Balancer	✗	✗	✗	✓	✓	✓	✗	✗	✗
SFC	✓	✓	✓	✓	✓	✓	✓	✓	✓

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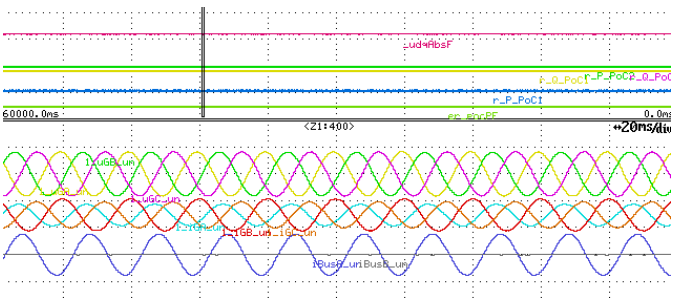
Case studies

Load balancer

Real time simulator results of a STATCOM operated as a load balancer maintaining the unbalance and power factor requirements on the three-phase grid by emulating a balanced load

Use case:
In a railway supply substation, one out of two feeding transformers is out of service which creates a worst-case unbalance condition for the three-phase utility grid, as only two phases are supplying the load and the other two phases are disconnected



Unbalance maintained at limit of 0.83%

PF maintained at 0.97 lag

Balanced three-phase voltage

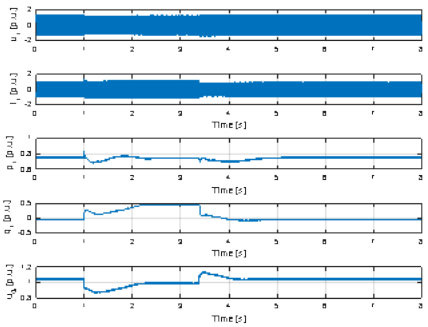
STATCOM current injection into grid

Only one feeder transformer supplying rail network

Static frequency converter (SFC)

Real time simulator results of the SFC for the Czech Rail, Říkovice site (50 Hz railway substation); dynamical stabilization of the catenary voltage by injecting reactive power.

Use case:
Supply of railway system by back-to-back converters in multiple railway substations, allowing to get rid of neutral sections, parallel operation of the SFCs



Single-phase catenary voltage

Single-phase supply current to catenary

Single-phase active power

Single-phase reactive power injected into the catenary.

Single-phase catenary voltage (p.u. RMS)

Conclusion

- Traditional high-speed railway power supply concepts seem to be straightforward and cost effective, however, properties of the railway system make special solutions necessary to limit detrimental effects
- Concepts based on power electronics (SVC, STATCOM, load balancers, RPC, SFC) have their specific advantages that should be compared to classical concepts.
- A holistic cost-benefit analysis in combination with a load flow study should be done for each high-speed railway power supply project to find the most appropriate solution.