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1311 - Protection System Analysis In Micrograds With DSO Static Generation

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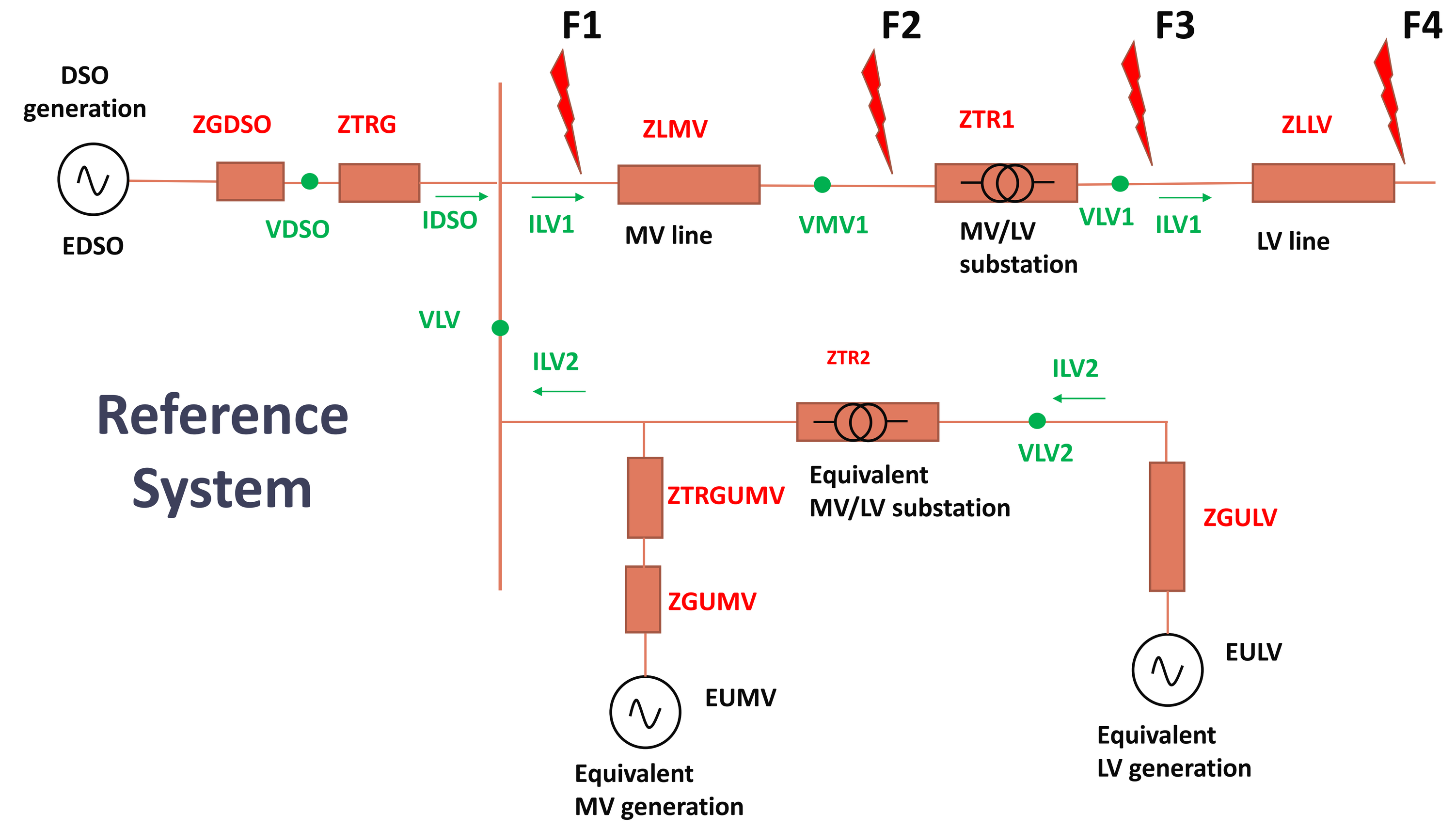
General Analysis with a Reference System

Extensive general analysis aiming at determining under realistic microgrid network configurations the **fault quantities** measured by the protection relays, based on:

- four **target faults** on MV and LV lines (F1, F2, F3, F4 in figure)
- a **parametric approach** involving: DSO and distributed generation (DG) ratings and **short-circuit (SC) current contribution**; MV/LV line characteristics and section lengths.



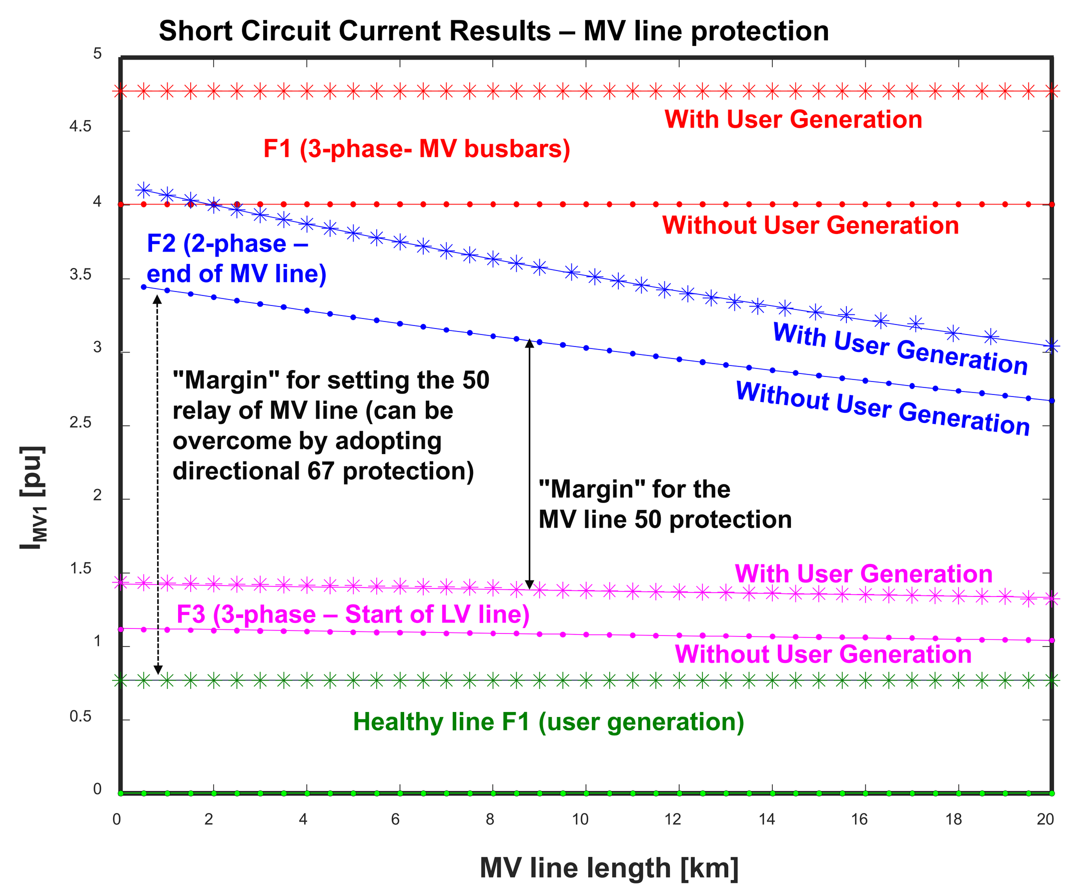
Protection setting parametric calculations

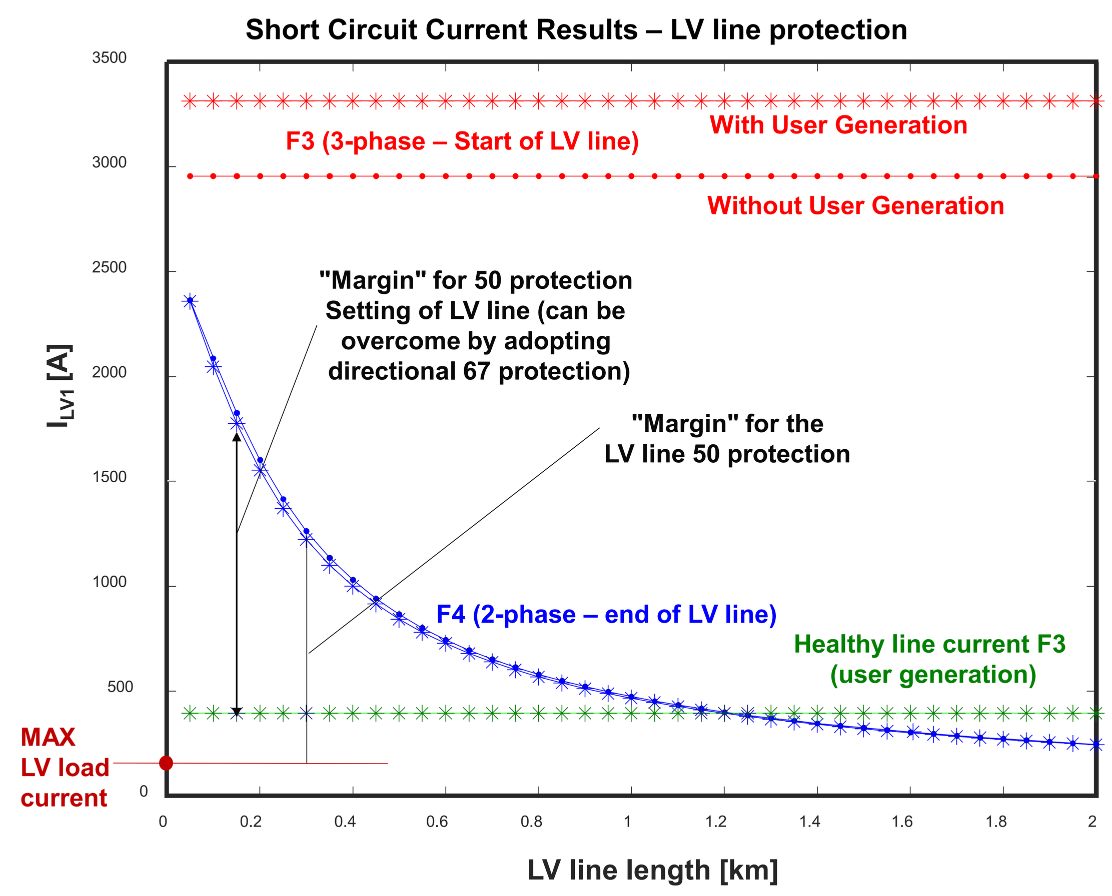
Calculation procedures and relevant graphical representations can be easily programmed getting **a general overview of the microgrid protection system feasibility in a very large range of conditions**. It can also be customized for specific microgrid, as a preliminary tool before more refined analysis.

General conclusions and quantitative limitations can be drawn for MV/LV protections; most important variables are the nature and the rating of DSO and MV/LV user generation.

Present **microgrid protection system loses selectivity over a given static generation penetration level and/or under a given overall generation rating**.

MV and LV protection settings: parametric analysis





The SC current level issue

To make "compatible" RES and protection selectivity, SC currents are (temporarily) needed!

Even in future totally static DSO/user generation scenarios, a protection/automation system based on over-current (O/C) functions is still necessary. A protection system based on the undervoltage, or differential principle is not realistically applicable to microgrids.

Possible related scenarios:

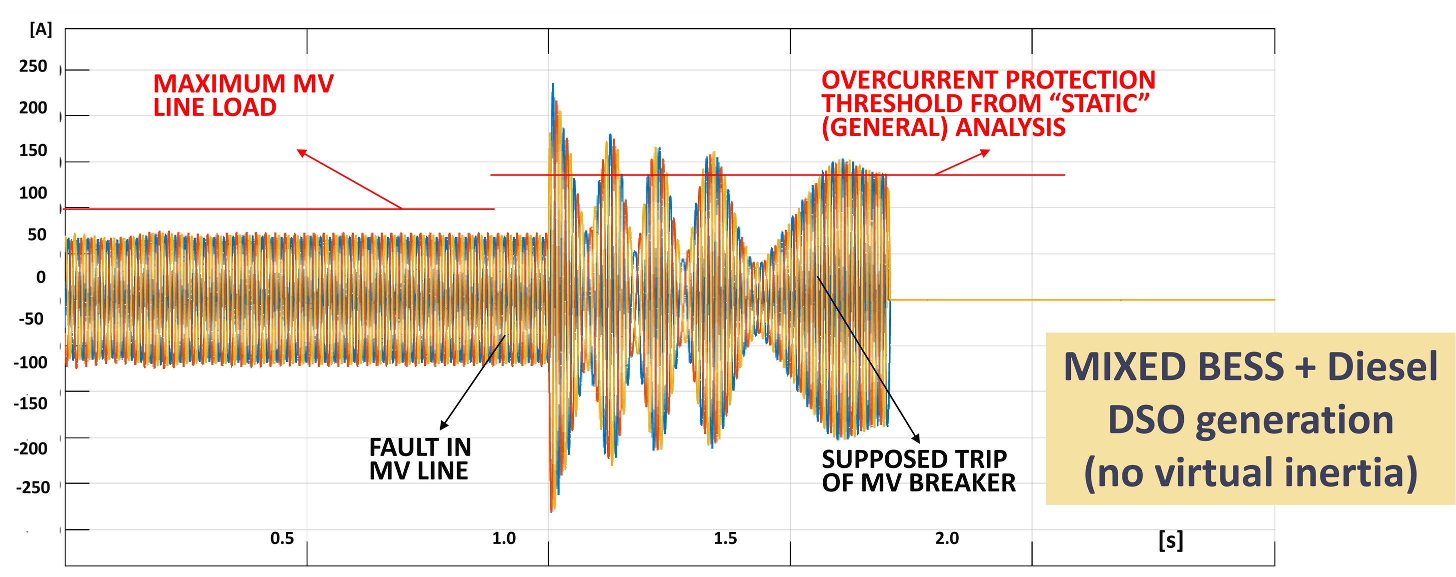
- **BESS with over-sized inverters** designed to supply SC currents much higher than the rated plant current
- **Additional "advanced" components** (permanently in service together with the static generation) capable of supplying short-circuit currents for at least few hundreds ms, such as Supercapacitors and Rotating UPS with flywheel solutions.

Refined analysis on real microgrids

A **couple of real microgrid applications** have been considered to support the present study. Their whole electric system (generation plants, MV and LV network/loads) has been detailed modelled (MATLAB-Simulink SW EMT-model, including control systems in the DSO generation (voltage/frequency regulators)).

Most calculations confirmed the adequacy/inadequacy of the O/C protection settings from the general analysis, with some interesting exceptions (mixed DSO generation with **additional control** is needed: see figure). This shows the **usefulness of a detailed microgrid model** in which the dynamic response of generation controllers is represented.

µGRID dynamic analysis



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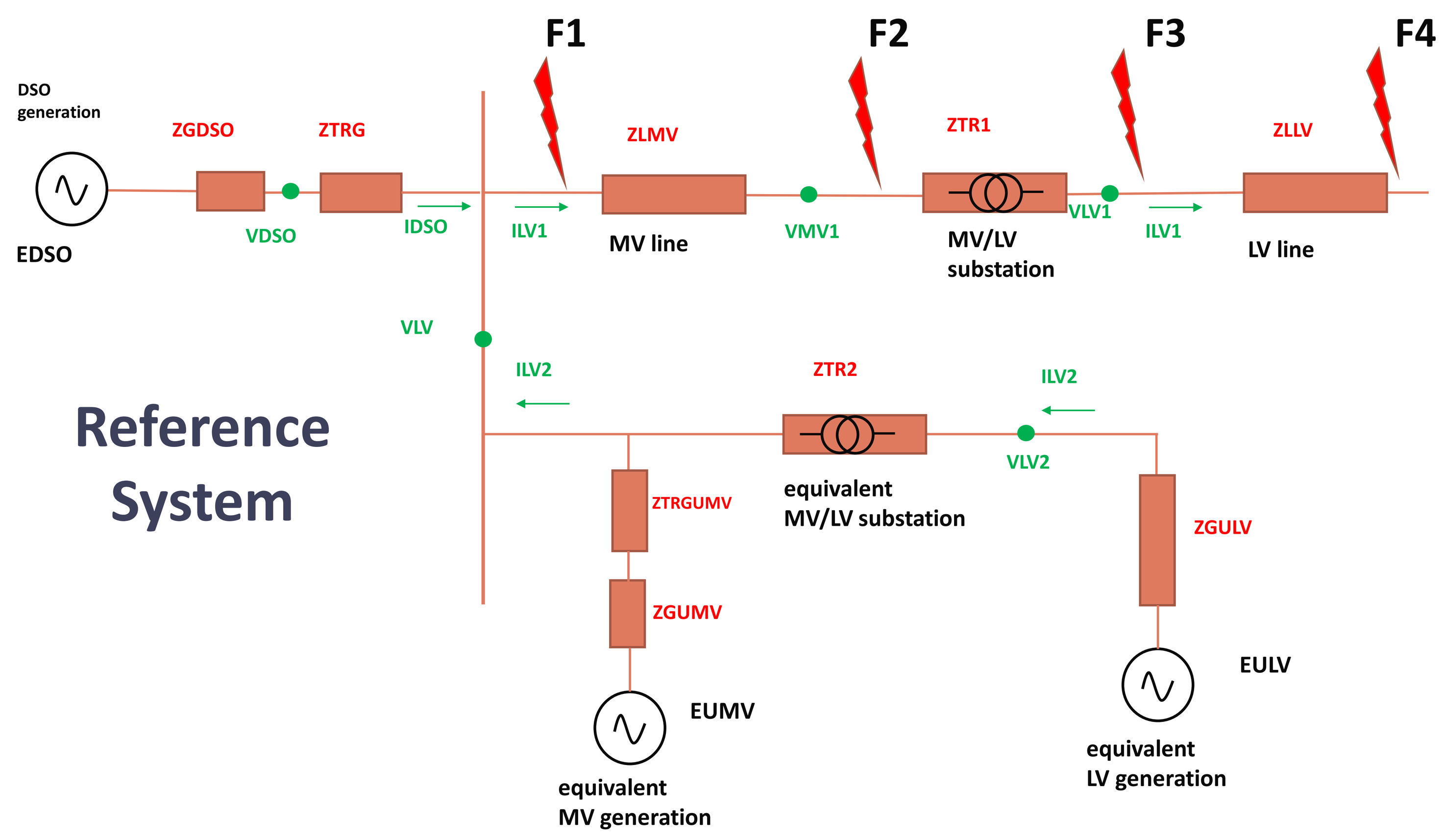
Short Circuit Target Faults

- **3-phase fault in position 1 at the beginning of MV line (fault F1)**: to evaluate the maximum short-circuit currents in the condition of both null and maximum MV/LV DG generation, to verify that the current ILV2 supplied by the set of DGs (all in operation) does not interfere with the chosen setting of the MV line O/C protections (MV line protections security verification).
- **2-phase fault in position 2 at the end of MV line (fault F2)**: Users' generators must not be considered to conservatively assess the minimum short-circuit current in the line under consideration (MV protections dependability check).
- **3-phase fault in position 3 at the beginning of LV line (fault F3)**: to set the LV O/C protection and verify that the MV line protection does not trip due to faults on the LV network (MV protections security verification).
- **2-phase fault in position 4 at the end of LV line** (fault F4): to evaluate the minimum LV short-circuit current for the different types of DSO generators (LV protections dependability check).

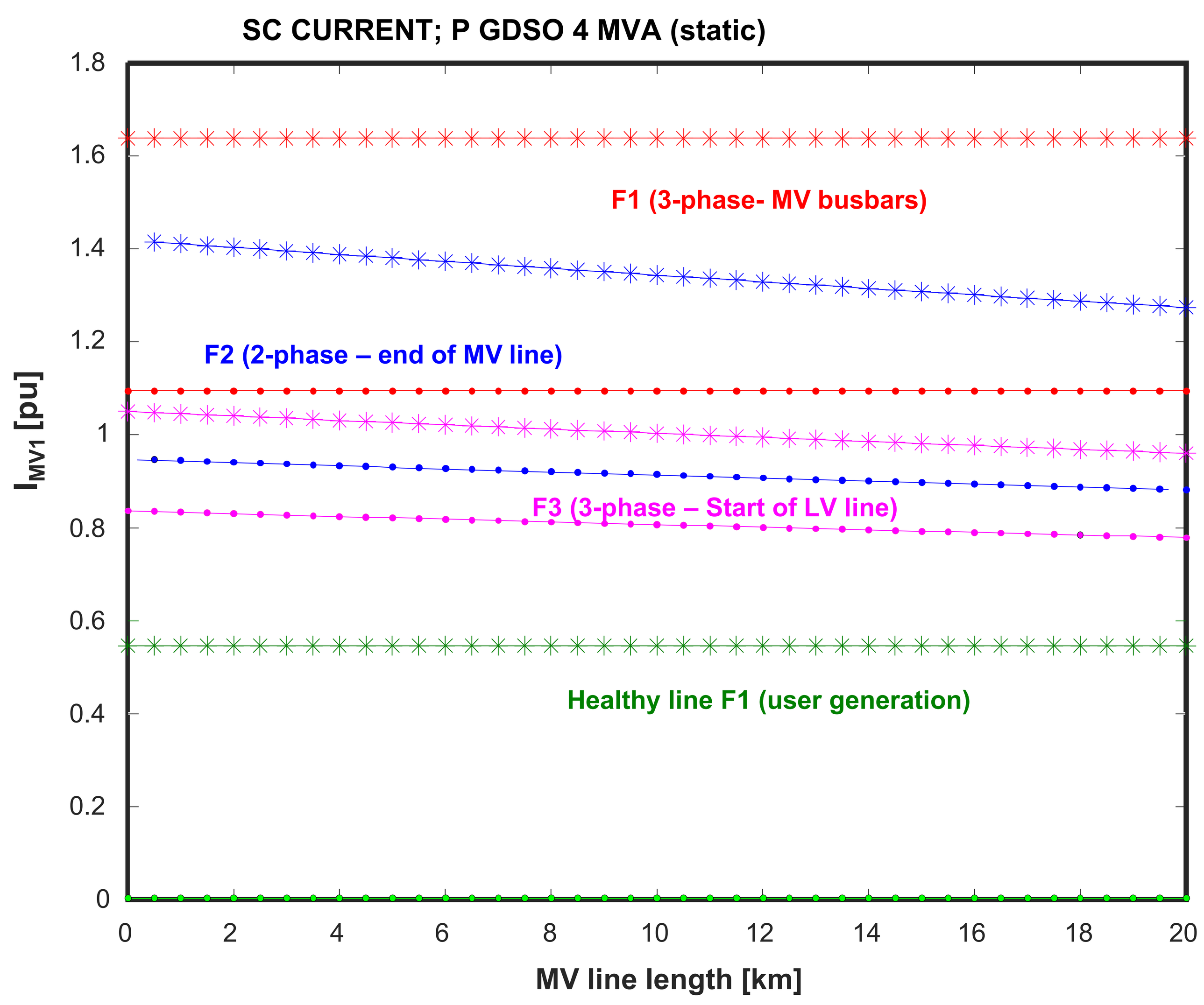


Parametric analysis assumptions

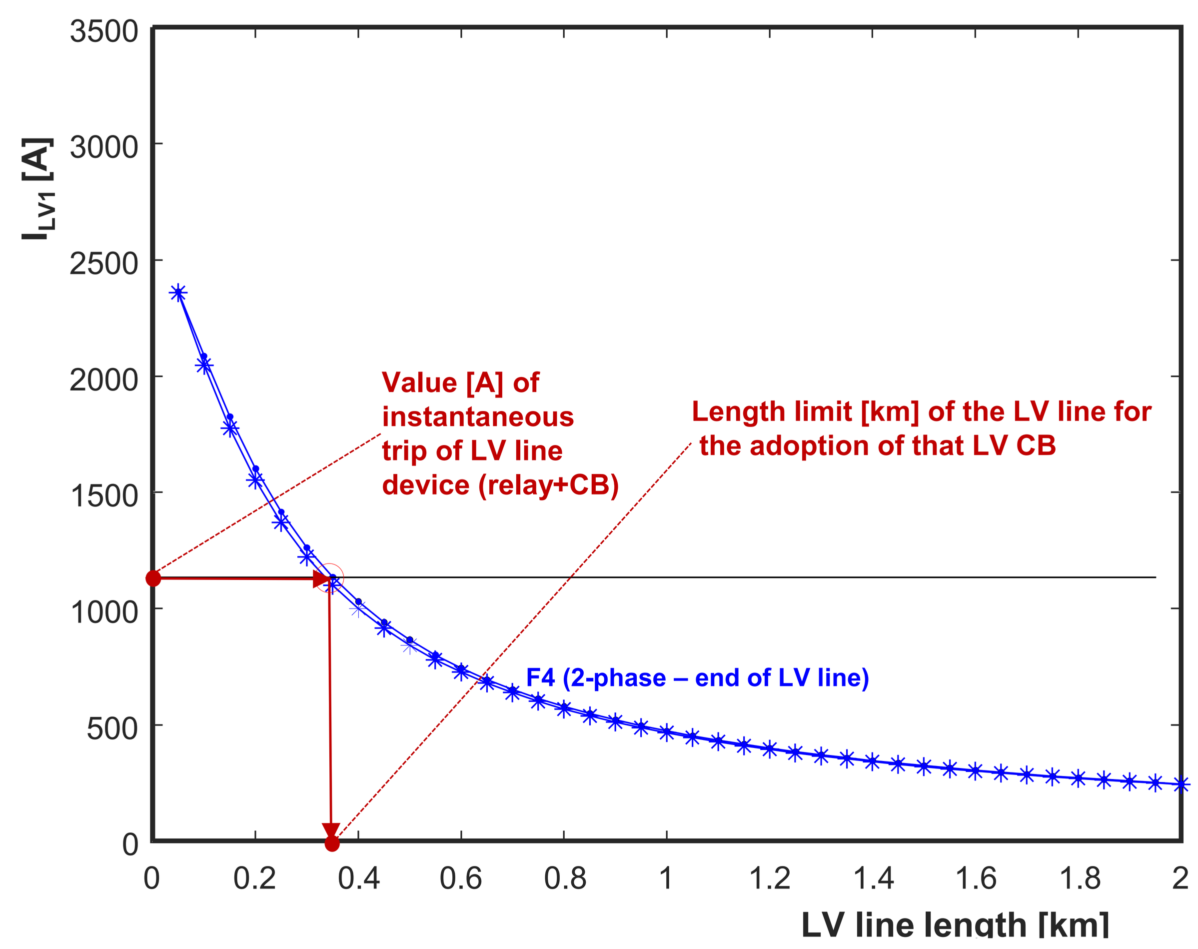
- Voltage levels: 15/20 kV (MV); 0.4 kV (LV)
- DSO generation ratings: 200 kVA ÷ 4 MVA
- Diesel Generator SC current contribution: $3 \div 7 \cdot I_{rated}$
- Static Generator SC current contribution: $1.1 \cdot I_{rated}$
- MV User generation ratings: 0.1÷0.5 of the DSO generation rating.
- MV line length: 0.1÷20 km (both overhead and cable). Relevant capacitive current contribution is in the order of few A (10 A as maximum limit).
- LV User generation ratings: 0.1÷0.5 of the "equivalent MV power", i.e., the SC contribution at the LV busbar of the MV/HV transformer (this contribution is given by both the DSO and the MV users generation).
- LV line length: 0.05÷2 km.

Example of MV protections miscoordination

- Prevalence of Static Generation with user generation 50% of DSO generation



LV line SC analysis (LV line length limits)



Detailed LV network representation