# Results for the Tutorial-DERHC, part IV.

This document shows the results of the Monte Carlo simulations evaluating the following characteristics: 66/22 kV transformer utilization level, the distribution transformers' maximum utilization level, the utilization level for 22kV conductors, and the percentage of customers with voltage issues. The number of simulations in this Monte Carlo study was 10, 30, 100, and 200.

For this case, and due to simplification purposes, the PV inverter control was not considered. On average, and depending on the user's computer specifications, each simulation without the PV inverter could last at least 1 minute, meaning that, in some cases, the Monte Carlo study contemplating 200 simulations could last more than 3 hours. On the other hand, if this control is active, each simulation can last up to 10 minutes, considerably increasing the computation times.

Figure 1 to Figure 4 present the Monte Carlo simulation results for the abovementioned characteristics. Boxplots are the most fitted plots for this type of study involving numerous simulations; they give an insight into the behaviour of the evaluated characteristics and the range of values in which the results are. Another essential factor to consider when doing this type of study is that the number of simulations is relevant: more simulations indicate a better tendency of the results. However, storing all the resulting data also requires more computation resources and time.

When evaluating the utilization level of the HV transformer, it is possible to see from Figure 1 that despite the number of simulations and the penetration percentage of PVs in the whole network, it never gets into a utilisation level above 100%. On the other hand, Figure 2 reveals that utilisation levels above 100% on distribution transformers are most likely to occur in penetration percentages scenarios above 60%. Figure 3 indicates that HV lines do not reach their nominal utilisation levels until 100% penetration scenarios.

Figure 4 indicates the general tendency of the rise in the number of customers with voltage problems when the penetration percentage of PVs increases. The size of the boxplots reveals that in the two highest penetration percentage scenarios, more than 80% of the customers do not comply with the statutory voltage limits.

From the first three evaluated characteristics, it is possible to observe that when increasing the number of simulations, the distribution and size of the boxplots change. Nevertheless, the changes from the 100 and 200 simulation cases are less evident than switching from 30 to 100 simulations, meaning that the Monte Carlo studies using 10 and 30 simulations are not representative enough. So, it is necessary to identify a suitable number of simulations to lead to representative results. Also, it must not be large enough to have computational problems.

A screenshot of a graph

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Figure 1. Boxplots for the Monte Carlo simulations assessing the HV transformer level of utilisation.

A screenshot of a diagram

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Figure 2. Boxplots for the Monte Carlo simulations assessing the maximum level of utilisation of distribution (LV) transformers.

A group of graphs with numbers and lines

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Figure 3. Boxplots for the Monte Carlo simulations assessing the maximum level of utilisation of high voltage lines in the circuit.

A group of white lines with black text

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Figure 4. Boxplots for the Monte Carlo simulations assessing the percentage of customers not complying with the statutory voltage levels.