The use of innovative tools in the medium voltage grid development, a case study of series voltage regulator

Balazs Tozser, Istvan Taczi, Akos Torok

Budapest University of Technology and Economics

Department of Electric Power Engineering

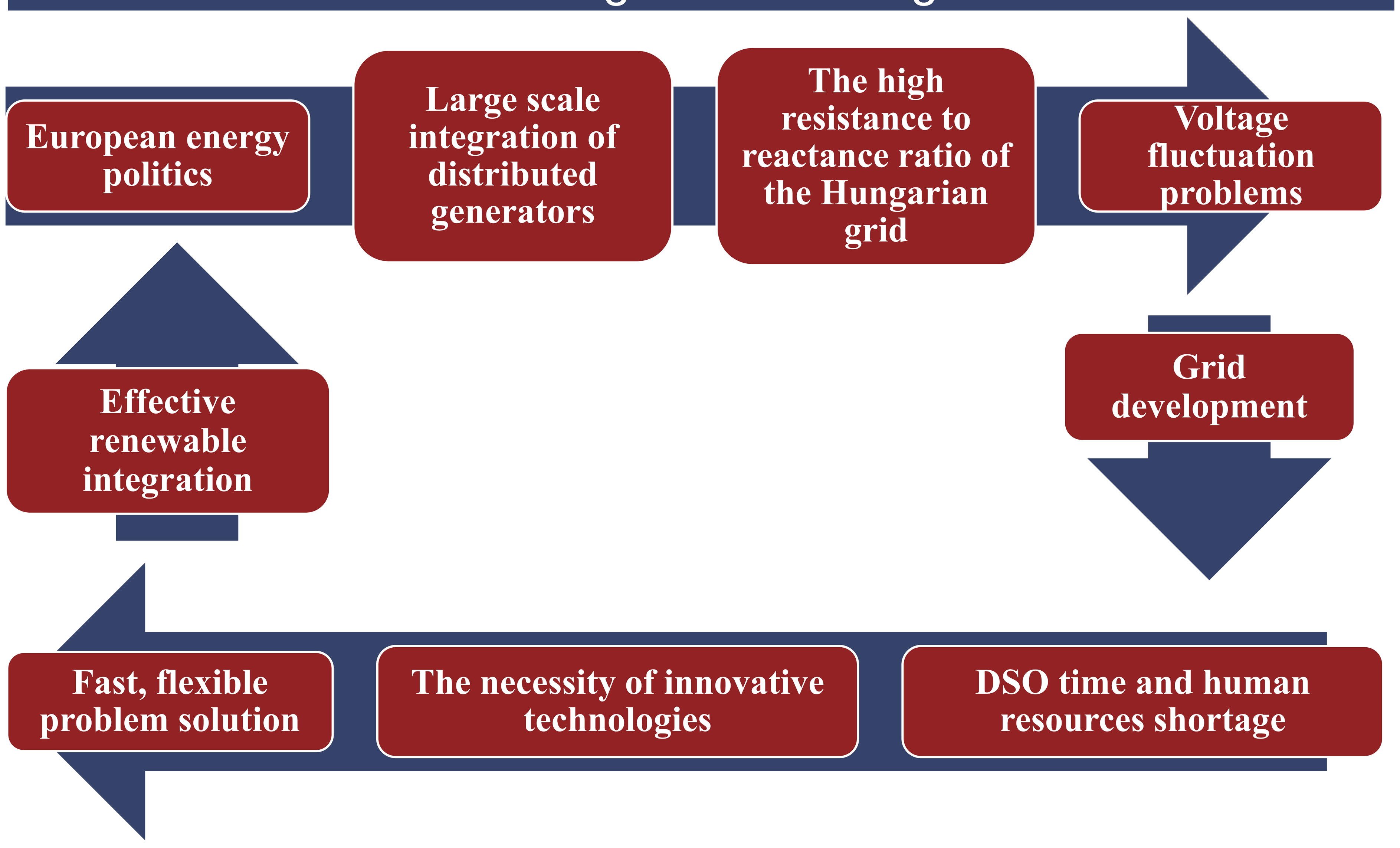
Email: tozserbalazs@edu.bme.hu

Abstract

The rapid technological improvements concerning the renewable energy sources and the energy policy of the European Union, and the National Energy Strategy are leading to a rapid increase in the number of intermittent renewable power plants. Thus, new challenges emerge in the operation of the distribution system. To operate the system efficiently, the use of innovative technologies must be considered, because conventional network development strategies cannot always provide an optimal solution for the problem. This paper analyses the effects of largescale wind power generation on a medium voltage system and a solution of the problems faced through a case study of a serial voltage regulator. The difference between the profiles of generation and loads causes the residential transformers at the end of the line to encounter large, more than 8% voltage fluctuation. To assess the site's voltage profile, time series symmetrical load flow calculations were performed. After the thorough analysis of the circumstances a serial voltage regulator device was implemented at 3 different nodes of the system and a placement analysis was carried out with statistical tools. The results showed a 3% decrease in the voltage fluctuation at the end of the line even when the device was far from these nodes; and with an optimal placement, the device could halve the largest voltage fluctuation on the line.

I. Introduction

Renewable generator integration



II. Methodologies

Country-level regulations and standards on voltage quality

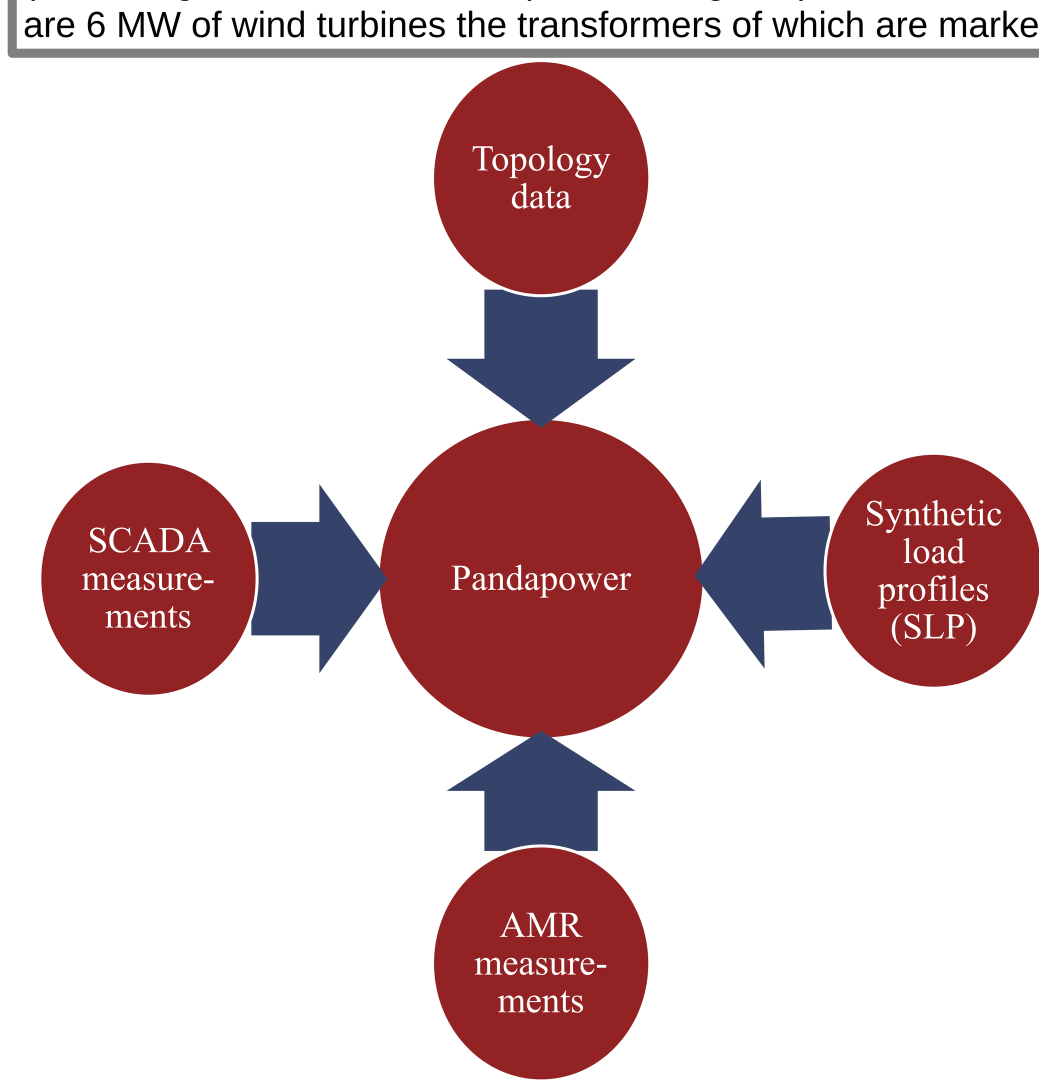
EN50160 - The effective value of line voltage (MV and LV) 95% out of the average value of the 10 minutes measurements in a week range, must be in the range of ±10%, while for the LV network must always be in the range of +10% -15%.

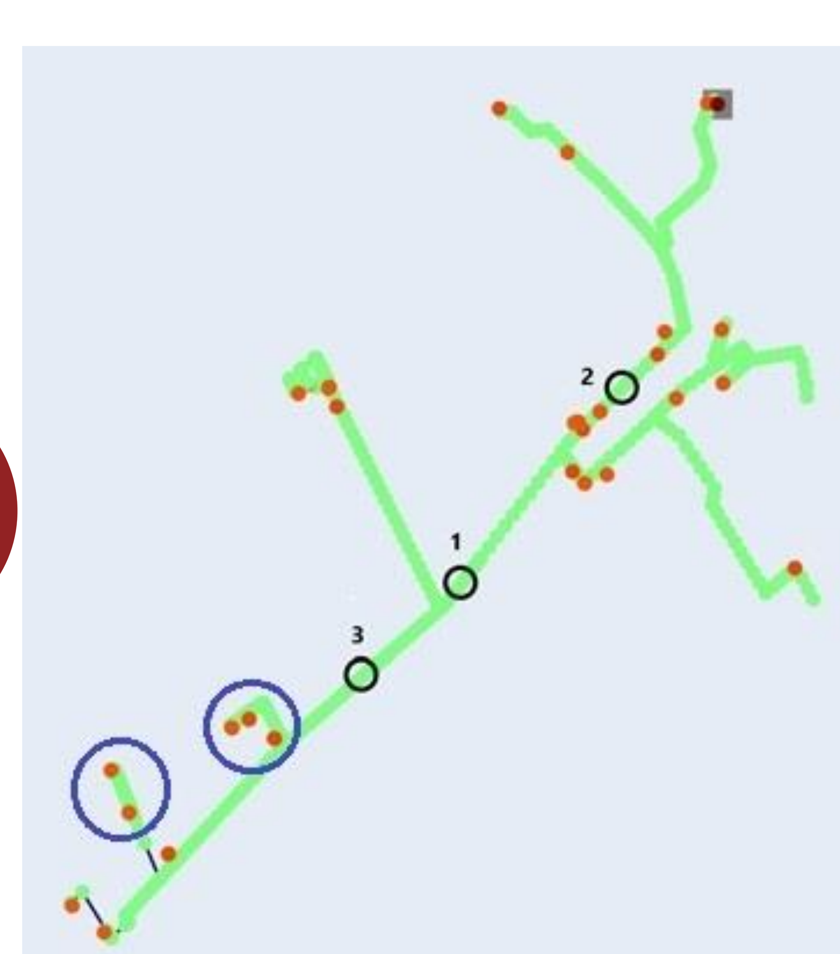
DSOs define guaranteed voltage quality services that contain an even smaller range for voltage magnitude, which must not be higher than ±7.5%.

The voltage fluctuation caused by the intermittent generators on the MV line propagates on the LV line as well.

Network and input data

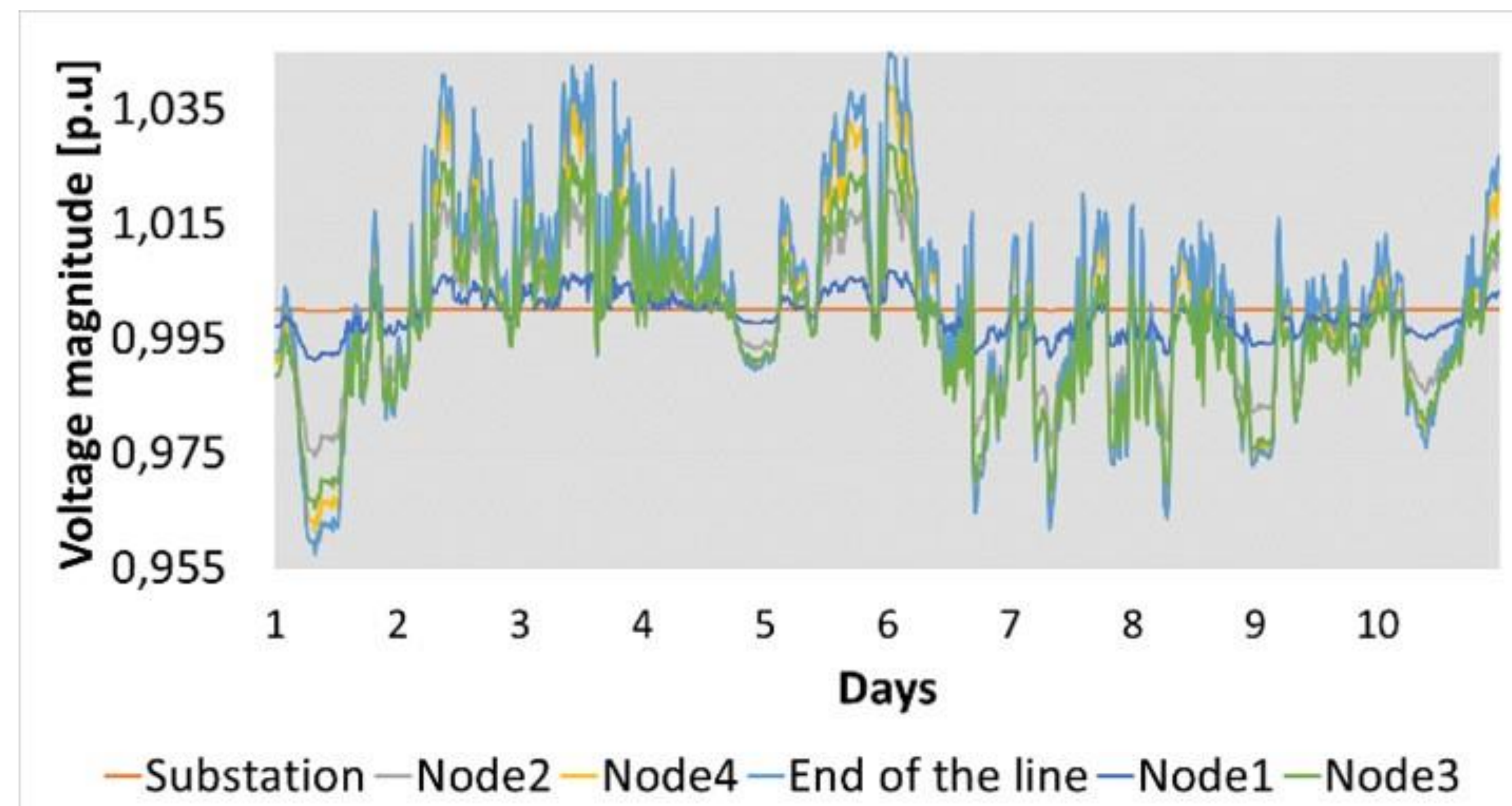
The picture bottom right depicts the considered network topology. The red dots are the locations of the MV/LV transformers connected to the 22 kV MV distribution grid. These were the transformers where the concentrated loads were applied. Besides the concentrated loads, time series measurements of active and reactive power values were available from the MV customers and from the wind turbine MV/LV transformer. The substation (external grid in the simulations) is in the right top corner, marked with a gray square. At the end of the line, there are 6 MW of wind turbines the transformers of which are marked with blue circles.





III. Simulation study

The simulation study was done in Pandapower, which is a Python-based programming environment. The goal was to simulate a MV line with high renewable penetration, and to analyze the voltage magnitudes along the line in the presence of the SVR with time series load flow calculations. To present the problems caused by the intermittent generation of wind turbines, the voltage-time diagram is presented. To present the voltage magnitude curve, 6 nodes were chosen: the substation, nodes 1–4 downs the MW feeder line, and the end of the feeding line. Even in the middle of the line (node 3) a fluctuation range of over 6% is present. At the end of the MV line, a magnitude of 8% voltage volatility can be seen, which results in the breaching of values engaged in the regulation, because the high value of voltage volatility at the beginning of the LV grid increases along the line.

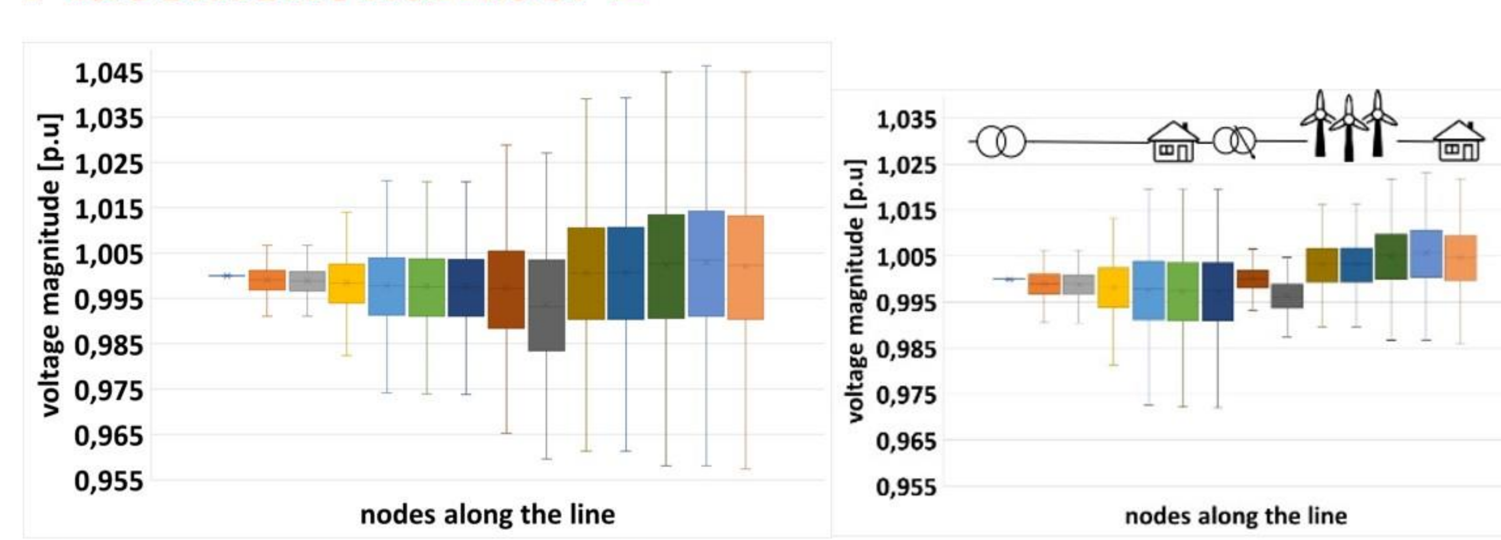


The above stated voltage fluctuation problem is easily solved with the use of an SVR device. A Series Voltage Regulator (SVR) is practically a series OLTC (On-Load Tap Changer) transformer. It shares the same control logic, but the technological representation is different. The device can regulate (increase or decrease) its secondary side output voltage, thus decrease the line voltage fluctuation.

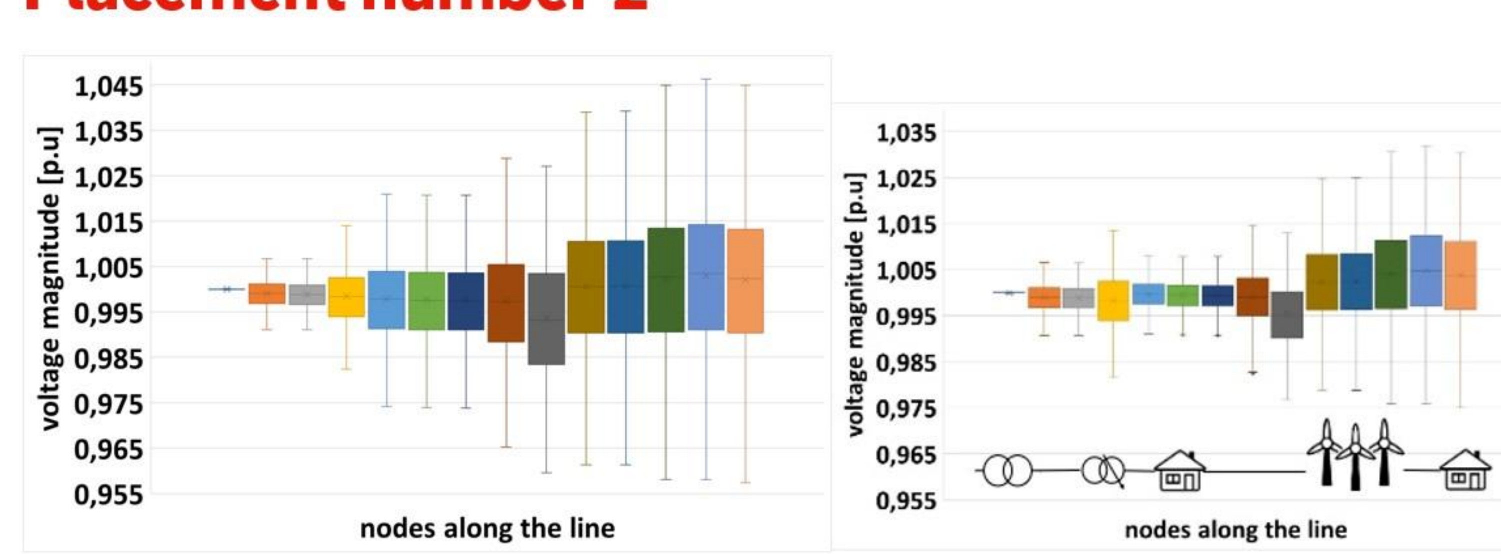
SVR placement analysis

The pictures below show box-plot diagrams for selected nodes of the feeder. The different colors represent different variations of voltage magnitude at nodes of the line. The selected nodes are critical in the measurement of the voltage magnitude.

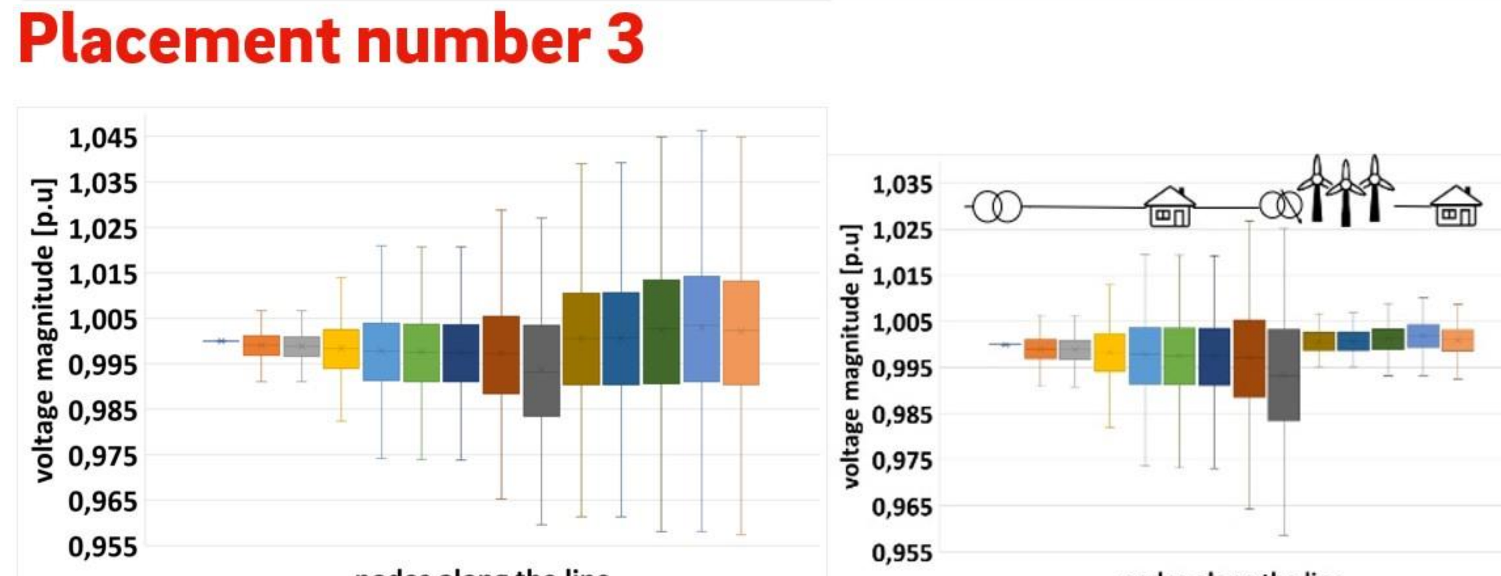
Placement number 1



Placement number 2



Placement number 3



The placement analysis discusses the optimal location of the device. 3 different placements were simulated, each considering a different aspect, and a tradeoff between satisfying all (MV and LV) or just certain customers. Number 2 and number 3 represent the two extreme options: number 2 being upstream, close to the residential customers at the beginning of the line, while number 3 is downstream, regulating the connection points of the wind turbines. Placement number 1 is a tradeoff between the previous two options. This combines the previously mentioned use-cases.

On the one hand there is a small town connected to the line upstream from the generators. On the other hand, there are also residential customers at the end of the line. Therefore, the optimal location for this device is placement number 1.

Conclusion

Based on the results, DSOs can understand the value of an SVR device from a realistic case study. The time series-based load flow analysis presented in this paper proves that it can be an accurate methodology to find the optimal placement for such a device. This paper also shows the limitations of the device, which is the inability to solve the voltage rising effect of the reverse power flow, upstream from the device.

Acknowledgement

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