DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

PhD Public Defence

Title:	Analysis of high PV Penetration Impacts and Reactive Power Management in Unbalanced Distribution Grids Including the Secondaries
Location:	Pontoppidanstræde 105, room 4.127
Time:	Wednesday 30 October at 13.00
PhD defendant:	Nuri Gökmen
Supervisor:	Professor Zhe Chen
Moderator:	Associate Professor Sanjay Chaudhary
Opponents:	Associate Professor Jayakrishnan Radhakrishna Pillai, Dept. of Energy Technology, Aalborg University (Chairman) Professor Ljupco Kocarev, University in Skopje, Macedonia Professor Peng Wang, Nanyang Technological University, Singapore

All are welcome. The defence will be in English.

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Abstract:

Environmental concerns have made governments and decision makers focus on clean energy policies to reduce greenhouse gas emissions and pollution. In this context, many countries have set ambitious targets to increase the share of renewable energy sources and accordingly lower the dependence on fossil fuels. As one of the most promising options, solar photovoltaic (PV) systems have become the fastest growing renewable energy sources over the last two decades. The remarkable rise of PV systems is expected to continue through the next decade and beyond with ongoing cost reductions and global decarbonization targets.

Even though the process is pleasing, with the increase in PV penetration levels some unfamiliar impacts are also introduced in distribution grids. Previously, when PV penetration levels were low, it was reasonable to assume that generation would offset the consumption and consequently eliminate the voltage drops, equipment loadings, and power losses. However, with the increase in PV penetration levels, these assumptions will no longer be valid; on the contrary, these problems will be exaggerated if necessary precautions are not taken in advance.

On the other hand, PV inverters are expected to play a key role in the near future. With the advances in power-electronics and communication technologies, state-of-the-art PV inverters now have the ability to provide ancillary services to the grid. Their operating points can be adjusted dynamically via intelligent control algorithms to reduce adverse PV penetration impacts. Some countries have already updated their PV interconnection standards promoting ancillary services such as active power curtailment and reactive power support from PV inverters.

It’s worth to mention that, although most PVs are interconnected to secondary distribution grids, individual voltage problems at the customer sides and service transformer overloadings are usually ignored in the analysis. Traditionally, residential customers in low-voltage distribution grids had only be seen as bulk aggregated load sources for higher level voltage network studies. However, due to the smoothing effect of the aggregation, the severity of the impacts may not be observed accurately in the secondary distribution grids. Therefore, it is crucial to include both primary and secondary sections of the grid and their components in the analysis to make more accurate inferences about the PV penetration impacts.

In this thesis, first, the technical impacts of high PV penetration on distribution systems are scrutinized considering voltage variations, voltage unbalance, line and transformer loadings, surplus power, power loss, and stress on voltage regulators. For this purpose, the distribution system is modeled as detailed as possible including both primary and secondary sides. In addition, time-varying high-resolution probabilistic load and PV generation profiles are generated individually considering a variety of device specifications, environmental effects, and human choices. Combining all of these components in a designed co-simulation environment, three-phase unbalanced power flow analysis is performed through winter and summer cases. According to the detailed analysis, problems are identified on a wide scale starting from the customer connection points to the substation in the case of high PV penetration.

Then, some mechanisms are investigated to maintain the voltage variations and voltage unbalance within the allowable limits. Accordingly, reactive power management strategies based on PV inverters are developed to mitigate the voltage variations and voltage unbalance by including the behavior of secondary distribution systems under high PV penetration levels.