## Influence of the phase-locked loop on the design of microgrids formed by diesel generators and grid-forming converters

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## Abstract-

In recent years, Microgrids (MGs with renewable energy sources, diesel gen-sets and droop-controlled converters have been increasingly used to guarantee the continuity of power supply in remote areas. Renewable energy sources have been typically connected to MGs by using an electronic converter that features the two controllers: a current-control loop and a phase-locked loop (PLL . Stability issues related to the PLLs application in electrical grids have already been addressed in the literature, however, dynamic interactions in MGs caused by PLLs have not been sufficiently explored. In this paper, a MG that includes a grid-feeding voltage source converter and a grid-forming device (diesel gen-set or converter is studied. All network elements are modelled analytically and the eigenvalue and participation-factor analyses are used to analyse the interactions between the devices. It is demonstrated that MGs formed by diesel gen-sets have reduced stability limits. Also, it is shown that stability margins of MGs formed by droop-controlled converters can be improved by changing the control parameters (e.g. PLL and internal controllers bandwidths . The main findings and conclusions are summarised and presented as a practical MG design guide. Theoretical results are validated in a lab environment comprising two 15~kW converters and one 75~kW grid emulator.

Index Terms- Microgrid, Phase-Locked Loop, Current Control, Diesel Generator, Droop Control, Small-Signal Analysis.

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