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State relevance and modal analysis in electrical microgrids with high penetration of electronic generation

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Abstract-

A clean electricity sector requires distributed generation through electronic power sources with very fast voltage, frequency, and current responses. Therefore, unlike in conventional power systems with slow generators, fast power-line dynamics may not always be negligible compared to generators’ dynamics. In this scenario, this paper proposes an algorithm to calculate the relevance of each state of a linear system in the system input–output response systematically. It explores its application to a linearised model of an electrical microgrid to decide which dynamics are relevant to be included for analysis and/or simulation. This algorithm uses a non-physical balanced realisation of the linear system, where the energy of each state variable in the system output can be calculated. Both the balanced realisation and the original system have the same eigenvalues. A “relevance coefficient” (RC) of each one of the state variables of the original linear system has been defined by combining the relevance of the states of the balanced system with the mode-in-state participation factors of the system eigenvalues of both systems. The usefulness of the proposed RC was validated by comparing detailed nonlinear simulations of an electrical microgrid with nonlinear simulations of reduced models as informed by the RC. Results show that the proposed RC gives sensible and clear recommendations even in systems without a clear time separation between system dynamics.

Index Terms- Distributed control; Dynamics; Reduced order systems; Modal analysis; State-relevance coefficient

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