The effect of network topology in electrical power grids

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The transportation of electricity from power plants to consumers centers is achieved by the transmission and distribution power lines. This electrical wiring shapes the power grid, an interconnected network built to provide electricity to the consumers. The grid is then constituted by nodes (generators/consumers) and the links (the power lines).

Network stable operation requires the nodes to run with the same frequency (50 or 60 Hz) and phase differences lower than a certain tolerance [1, 2]. If the two requirements are achieved the network is said to be synchronized.

In this condition, network theory allows us to make an abstraction of the transmission system to study how the structure of the network affects the electrical signal properties. It is well known that the changes on the network topology in this systems directly affects the natural frequencies of the system [3], and consequently, the network synchronization and the signal quality. Therefore, this study is directly related to give theoretical support to possible technical issues.

We faced this work by using analytical and numerical techniques. First of all, we modeled small power grids with different topologies to study how this differences affect the natural frequencies of the system (see Fig. 2). In a second stage, we performed a similar analysis on the structure of real grids, by modeling the electrical power grid of Balearic Islands (see Fig 1).

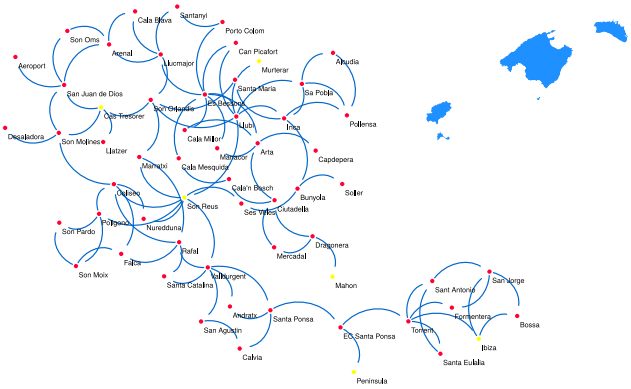

Fig. 1. Representation of the power grid in Balearic Islands, Spain.

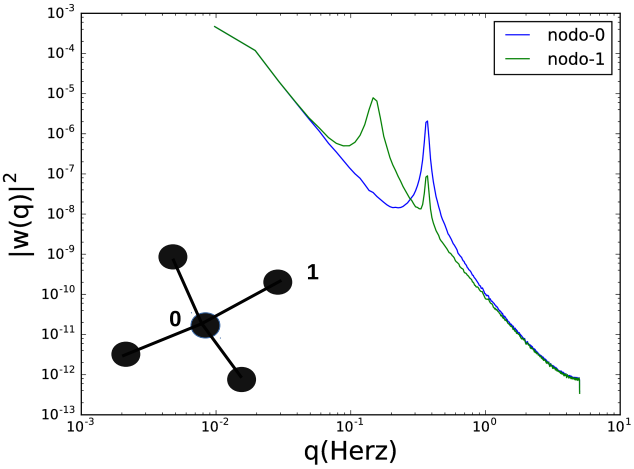

Fig. 2. Frequency signal power spectrum, for two nodes in a power grid with star topology.

[1] F. Dörfler, M. Chertkov, and F. Bullo, Synchronization assessment in power networks and coupled oscillators, Proc. Natl. Acad. Sci. USA **110**, 2005-2010 (2013).

[2] J. W. Simpson-Porco, F. Dörfler, and F. Bullo, Voltage collapse in complex power grids, Nat. Commun. **7**, 10790 (2016).

[3] L. M. Pecora and T. L. Carroll, Master stability functions for synchronized coupled systems, Phys. Rev. Lett. **80**, 2109 (1998).