Master's Thesis : Dynamics and control of low inertia power networks with high penetration of renewable energy sources

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Dynamics and control of low inertia power networks with high penetration of renewable energy sources

Graduation Studies conducted for obtaining the Master's degree in Electrical Engineering by ROMANE DRAGOZIS

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Nowadays, power systems are mainly composed of conventional power plants connected to the grid through synchronous machines. However, renewable energy sources see their establishment grow with time, especially wind power and photovoltaic plants but also energy storage systems, to reduce CO_2 and other greenhouse gases emissions. These technologies are connected to the grid through power electronics devices, that decouple them from the network and protect them from any inertia response contrary to synchronous machines. This lack of inertia jeopardizes the system stability and has harmful effects in terms of the frequency response but also on the voltage stability.

This work thus focuses on the study of such transmission networks with high penetration of renewable energy sources. The first chapter targets on the network stability theory. It includes an overview of the main system parameters as well as their effect on the network stability and focuses especially on the frequency response and the voltage stability.

The second chapter is dedicated to the influence of inertia in the network. Definition of inertia in power systems is given using the swing equation as well as the interpretation of inertia together with the link between this measure and system frequency or voltage. The load participation in the frequency response is also discussed as it has an influence on the system and finally the aggregated model of a whole power system is given.

In the third chapter, three main sections are developed, focusing on low inertia networks. The first one consists of the consequences that the lack of inertia has on power systems stability, in terms of frequency, voltage, over-current and black-start capabilities, system parameters and power reserves. It thus focuses on the way the system reacts to severe faults where the second section introduces energy buffer technologies together with solutions that can be implemented for 100 % power electronics-based systems to participate in frequency and voltage regulation. Finally, the third section focuses on the particular case of the converters connecting the renewable energy source to the grid either in grid-following or grid-forming mode. The definition and the characteristics of each converter as well as the motivation behind using grid-forming converters is given. The models of each converter used in the simulations is described as well in this chapter.

The application to the Nordic network is discussed in the fourth chapter. The simulation tools that are used are presented in addition to the topology of the studied network. Its initial operation is illustrated and then two types of simulations are presented. The first one consists in depopulating a region of the network of synchronous machines and replacing them with renewable energy sources connected through converters while the other configuration makes use of a HVDC link that imports active power out of an interconnection. Each configuration is studied in terms of frequency response and voltage control and different technologies mixes are proposed to obtain the most appropriate one.

Finally, the fifth chapter gives an overall overview of the remaining and encountered challenges linked to the high penetration of inverter-based energy sources while the last chapter concludes the entire work.