Effects of DDC on the Synchronization of the Electric Power Grid Network

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Synchronization constitutes one of the most dominant collective dynamics of complex network in social, biological and technological systems, such as communication networks, food webs, power grids and so on. The synchronization of the network deeply depends on the dynamics as well as the topology and internal properties such as the strength of the coupling of an element with the rest of the network. The electric power network is designed to operate in the synchronous state, namely the state where the units of the network behave identically with the same frequency ($50Hz$ or $60Hz$) and with constant different of phase [1]. How stable, resilient and robust is the network is determined by its aptitude to remain synchronized against perturbations such as power failures [2]. These perturbations may cause a desynchronization of the nodes which can favor the emergence of destructive power oscillations and somehow may lead to blackout or cascading blackout if the node affected is not disconnected from the network. Therefore, it is important to control the power grid in such a way that it is resilient against failures and local instabilities [3]. Thus severals works have proposed methods for controlling power grid stability by stabilizing the frequency fluctuations which is the cause of desynchronization. Indeed, any generation/consumption unbalance which can be due to an input power coming from intermittent renewable energy sources or to a sudden increase in demand, lead to a variation of the frequency for a particular power source or node. Severals concepts have been proposed to stabilize the frequency grid such are: the Frequency Adaptive Power energy Re-scheduler(FAPER), which is the idea of individual load control through responding to frequency. Demand response programs which are programs allowing user to consume electricity within different windows or depending on the real time price of the electricity in order to avoid peak of consumption. Dynamic Demand Control (DDC), which is a low cost technology than can be easily integrated in smart appliances (refrigerators, air conditioners, laptops, dryers, washing machines . . .), and enables them to switch on/off according to the grid frequency. It has been observed for the case of a single generator with fluctuating loads that a good stabilization of the frequency is achieved. Yet some rare events characterized by a huge frequency deviation appear due to the recovering of pending task. Including smart communication among devices can suppress these large frequency peaks [4, 5].

In this work we consider a network of power plants instead of a single generator and study how DDC improve the synchronization properties. Fig. 1 shows the network topology which has an average degree $\langle k \rangle = 2.5$. Fig. 2 shows how the frequency fluctuations as well as the phase differences are reduced.

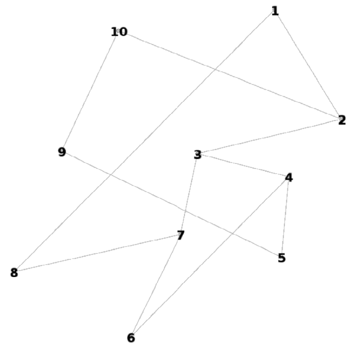

Figure 1: Network topology

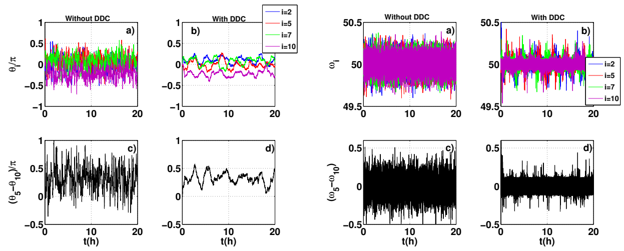

Figure 2: Time evolution of the phase, frequency fluctuations at each node, and phase and frequency differences between nodes 5 and 10 without and with DDC.

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