Analysis of the blackout risk reduction when segmenting large power systems using HVDC lines

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Large electrical transmission networks are susceptible to undergo very large blackouts due to cascading failures. For instance, in 2003, a blackout in Italy produced by a cascading failure affected 55 million consumers. Despite this risk, the typical power system engineering planning approach has been for decades to build the largest possible networks. Recent studies suggest, however, that it would be beneficial to segment them [1, 2]. As a matter of fact, Ref. [1] suggests that there is an optimal size in terms of security and risk. Small power systems are more vulnerable but very large power systems can have huge blackouts with an extraordinary large associated cost. The trend to segment power systems has already started in China, where the Yunnan zone has been segmented from the main synchronous system where it was connected, to reduce the risk of a cascading blackout [3]. Several studies are considering the option of applying similar measures in Europe or North America [2]. The concept of segmentation is based on the idea of dividing a large alternate current (AC) synchronous area by introducing high voltage direct-currel (HVDC) lines to interconnect smaller asynchronous zones. HVDC allows to exchange power between the segmented zones while preventing the spread of severe disturbances thanks to active and reactive power control capability of converters.

In this work we propose a method to segment power systems using HVDC lines to reduce the risk of blackouts. The blackout risk is estimated using the ORNL-PSerc-Alaska (OPA) model [4, 5]. The OPA model is based on a combination of fast and a slow dynamics. The first describes the cascading failures while the second the grid evolution through line and generation upgrades as a respond to failures and demand growth. This way the model brings the power grid continuously to a critical state where random failures may trigger cascading blackouts. The sizes and frequency of the obtained blackouts can then be used to estimate the overall blackout risk of the network. The method to segment grids, like the one shown in Fig. 1a), consists in controlling the power flowing through HVDC lines during cascading failures in order to minimize the load shed of each blackout. As a result, the segmented grids have a substantially lower risk of blackouts than the original network (Fig. 1b). The control method is shown to work efficiently if the network is segmented in zones of similar size.

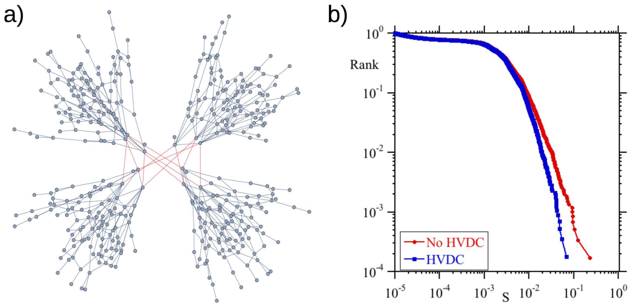

Fig. 1. a) Segmented network constructed by interconnecting four 100-nodes zones with three HVDC lines between each pair of zones (red lines). b) Rank function of the normalized size of the blackouts (S) for the 4x100 network using standard AC lines to interconnect zones (red symbols) and using controllable HVDC lines (blue symbols). A reduction in the probability of large blackouts is clearly appreciated.

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