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Review on Network Restoration Strategies as a Part of the RestoreGrid4RES Project

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Introduction

The increasing amount of renewable energy sources (RES) changes operation of electrical power systems, not only during normal operation but during emergency operation as well. In any network area which has a low inertia, the system frequency is more volatile. The integration of RES and the related replacement of conventional power plants which effectively provide inertia lead to increase of rate of change of frequency. For instance, the power outage in Australia in September 2016 was caused by insufficient inertia [1].

RestoreGrid4RES is a research project that investigates potential problems and challenges during the restoration caused by a high penetration of distributed energy resources, often in the form of RES. The aim is to support a fast and secure grid restoration in case of a blackout in networks with a high share of renewable energy generation. As a first step in the project, a review of network restoration strategies and analysis of the impact of high penetration of RES are conducted. New grid restoration strategies will be developed based on the review.

Method

In the event of a system-wide blackout, there have to be restoration strategies available, which determine how to restore the electricity system. Top-down and bottom-up re-energization strategy are defined in [2]. According to the Article 24 of the ENTSO-E Network Code on Emergency and Restoration, each transmission system operator (TSO) is entitled to combine top-down or bottom-up re-energization strategies as needed [3]. For the sake of clarity, a distinction between top-down, bottom-up and a combination of top-down and bottom-up is made as follows:

- Top-down strategy exclusively requires the assistance from neighboring TSOs to reenergize the system of a TSO;
- Bottom-up strategy requires no assistance from other TSOs and power sources with black start capability are available in the own control area of a TSO or subordinated DSOs for self-reenergization;
- Combination of top-down and bottom-up strategies use the assistance of other TSOs as well as power sources with black start capability being available in the own control area of a TSO or subordinated DSOs for re-energization.

Both top-down and bottom-up re-energization strategies indicate the coordinated action between TSOs of different control areas in restoration state. However, in the definition of bottom-up strategy, it is not defined whether black start is provided in the grid of the TSO, a distribution system operator (DSO) or by both of them. Therefore, build-down, build-up and build-together strategies are introduced to clarify the relation between TSOs and relevant DSOs. Some or all strategies can be applied together with either a top-down or a bottom-up re-energization strategy, or a combination of both.

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Matrix of Network Restoration Strategies

A matrix representing possible combinations of network restoration strategies is illustrated in Figure 1. The sequence of restoration actions, which include voltage forwarding, black start and resynchronization, is also illustrated in the matrix. build-down, build-together and build-up strategies can also be combined, as restoration of the disturbed systems of several DSOs connected to the same TSO may be conducted in different ways. This is not shown in Figure 1 to avoid a further expansion of the matrix.

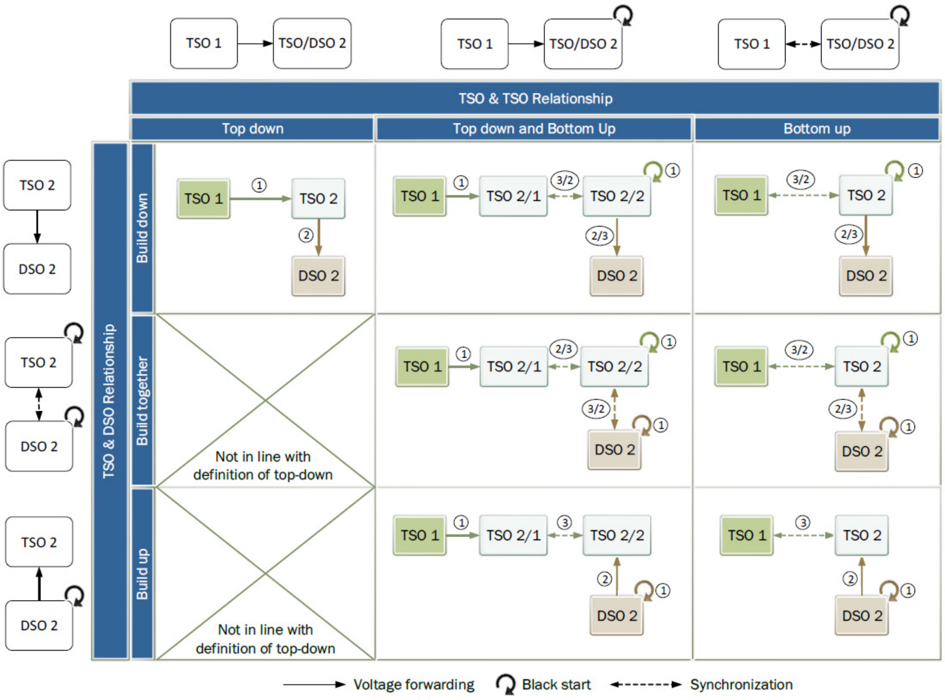

Figure 1: Matrix of network restoration strategies

Impact of Integration of Renewable Energy Sources in Restoration State

As mentioned in the introduction, one impact of integration of RES on network's operation is a more volatile frequency in case of power imbalance. Furthermore, automatic reconnection of dispersed generation to the network at a pre-defined value of frequency can cause serious consequences in islands during restoration and is a major challenge. This may result in substantial increase of frequency, so that other generating units are disconnected, or as a worst case, system collapses again [4].

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