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FOND ZA ZAŠTITU OKOLIŠA I ENERGETSKU UČINKOVITOST

Integration of flexibility sources in distribution network

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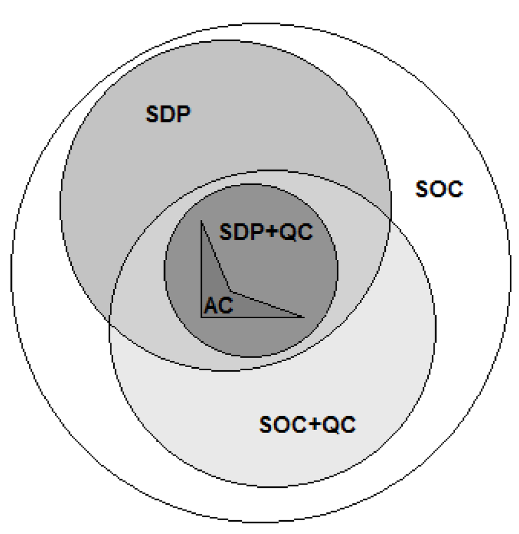
1. Introduction

Regulatory bodies are setting ambitious goals to increase the share of renewable energy sources (RES), increase energy efficiency and reduce carbon emissions. Distribution network used to be operating according to “Fit and forget” doctrine. The grid has been oversized to ensure secure operation during critical incidences. The distribution grid, which has traditionally been a passive network, characterized by single direction power flows, little available information on the grid and no interaction of the final user with the upstream system, will go through significant changes. Because of intermittent nature of renewable sources, a new approach for distribution system control is required to avoid reinforcement cost. Active Distribution Network Management has to provide more flexibility and be capable of maintaining supply-demand balance over different time periods.

2. Models for distribution network planning and operating

Due to different characteristics of transmission and distribution network, such as network topology or X/R ratio, different models are used for operating the distribution and transmission systems. Mathematical models used for planning and operating transmission network are simplified and approximated, but can not be applied for distribution system. Active losses, voltage amplitudes and reactive power can not be ignored in distribution network calculations because of volt/VAR control.

Different techniques are used for calculating power flows in distribution system: iterative methods, such as Gauss-Seidel or Newton-Raphson, and optimization methods. Equations related to AC power flow are non-linear and non-convex. To ensure global minimum in optimization process, objective function and constraints have to be convex function. Equations are relaxed using Semidefinite Programming (SDP), Second-Order Cone Programming (SOCP) and guarantee global optimal solution.

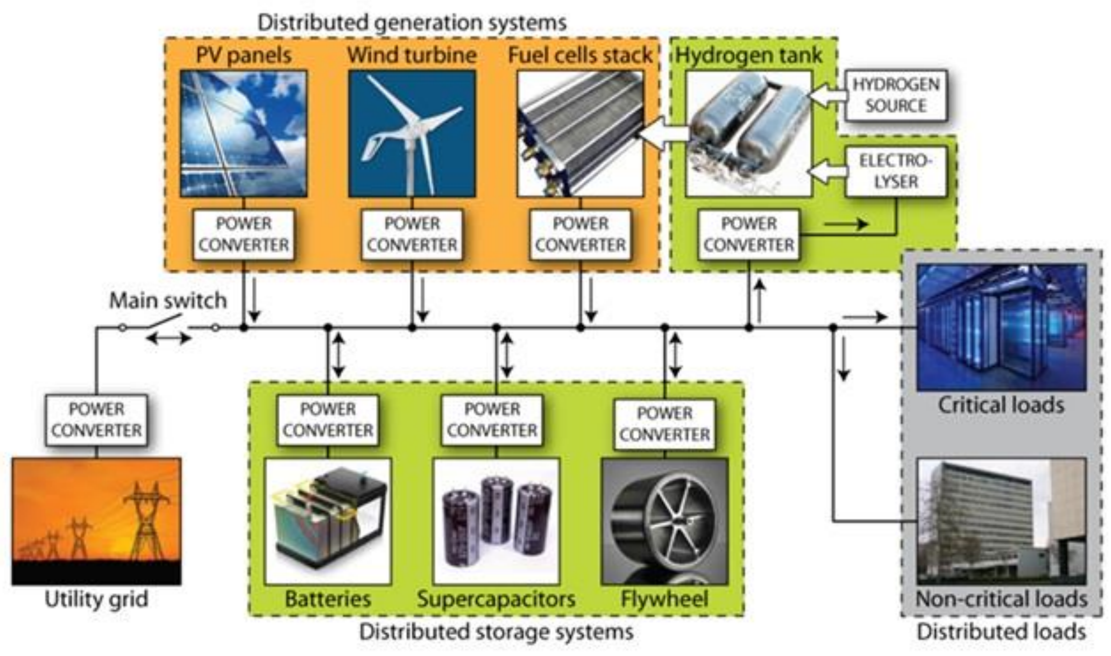


There are many AC optimization models for calculating (optimal) power flow. Two of them are Bus Injection Model (BIM) and Branch Flow Model (BFM). BIM focuses on nodal variables and BFM on branch variables. Models are equivalent, but only presented in different variables.

Depending on the model, new variables are introduced for the product of two voltage variables or squared current variable. In BIM positive semidefinite matrix with rank 1 is formed. Rank-1 constraint is the only source of non-convexity and is simply dropped from calculation. The relaxed model is then optimized and the rank constraint is checked in post processing.

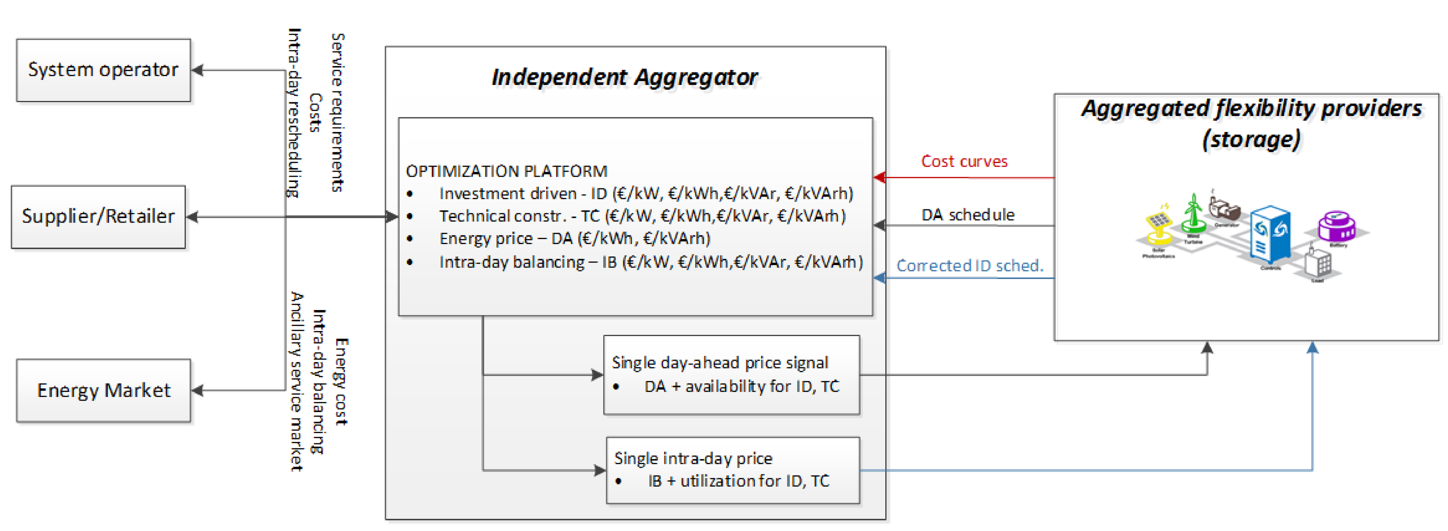
3. Flexibility sources

Due to broad integration of volatile renewable energy sources in distribution system, distribution system operator (DSO) has to operate the system within the technical limits providing full-time and high-quality energy supply. Distribution networks have been constructed for one-way power flow (from generators through transmission network to the consumers in distribution network). As generation from RES can not be controlled, during the period of low consumption and high production, reversed power flow occurs and causes congestion on the HV-MV transformer. To avoid such problems and maintain the system within technical limits, distributed flexibility sources can provide diverse and multiple service. Demand response and battery storages could reduce operational cost and improve the efficiency and security of distribution network by reducing unplanned power flows, grid congestion, voltage and frequency variations.



4. Flexibility services

Responsibility for operating energy storages in distribution network, as well as the demand response, has not been not legally determined yet. The main focus is on determining who will install and own storages in distribution network, as well as the size and characteristics of the storage and its position in distribution grid. Flexibility sources owned by DSO could provide system stability and assure reserve, but different stakeholders, such as energy traders (operating storage in arbitrage purpose trying to maximize their profit-charging at the low price and discharging at high price) could cause congestion or voltage violation.



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