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TSO–DSO interaction: Active distribution network power chart for TSO ancillary services provision

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ABSTRACT

Within the timely framework examining interaction modes at the interfaces between transmission system operator (TSO) and distribution system operators (DSOs), this letter proposes the new concept of active-reactive power (PQ) chart, which characterizes the short-term flexibility capability of active distribution networks to provide ancillary services to TSO. To support this concept, an AC optimal power flow-based methodology to generate PQ capability charts of desired granularity is proposed and illustrated in a modified 34-bus distribution grid.

1. Introduction

Enhanced cooperation between transmission system operator (TSO) and distribution system operators (DSOs) is a timely key factor, underpinned by growing research initiatives [1–3,5], to facilitate a safe massive integration of renewable energy sources (RES) in power systems. For example, several coordination schemes modelling potential interaction modes between TSO and DSOs at their interface have been investigated [3,4]. To support TSO–DSOs cooperation, the letter proposes the new concept of active-reactive power (PQ) chart (or feasible region) to characterize the flexibility capability of active distribution networks (ADNs) [6] to provide ancillary services (e.g. frequency control/power balancing, congestion management, or voltage support/security [3]) at the TSO–DSO interface so as to aid the secure operation of the transmission network. The concept is examined in short-term basis, i.e. up to tens of minutes ahead operation, where uncertainty could be neglected. Without loss of generality, this work assumes a TSO–DSOs interaction mode in which each DSO provides to the TSO, at some agreed time horizon, the proposed PQ flexibility chart for which ADNs constraints are met. The TSO can then optimally activate (e.g. for balancing purposes) this flexibility and notify the DSOs to change the setpoints accordingly in the ADNs. Iterations between TSO and DSOs may be possible to ensure that constraints are satisfied in the combined transmission/distribution system via, among others, shared use of ADNs flexibility.

The proposed PQ chart concept shares some similarity with the approach in [7], where the range of RES reactive power capability is aggregated (for a given active power exchange) at the TSO–DSO interface. This letter leverages significantly the concept to PQ charts in a comprehensive manner by considering an optimal management of ADNs via centralized active network management (ANM) schemes [6] including: on load tap changer (OLTC) transformers, RES active/reactive power, voltage-led demand reduction [10] assuming a voltage dependent load model, and demand response (DR).

While this letter was under review, the similar concept of estimating the active and reactive power flexibility area at the TSO–DSO interface was proposed [8]. This concept was further developed in [9], which explores the impact of discrete variables on the flexibility area, showing that the latter may be composed of disjointed parts corresponding to different values taken by discrete variables. This letter differs from these works [8,9] mainly in terms of: problem formulation (rectangular vs polar voltage coordinates), approach to generate the PQ chart (ϵ-constraint vs tangent lines), and a few modelling aspects (e.g. voltage dependent load models, flexibility cost, etc.).

2. The proposed methodology

To address this new operation need and generate the PQ capability chart of an ADN, the proposed methodology relies on solving a sequence of tailored AC optimal power flow (OPF) problems. These latter are formulated using complex voltage rectangular coordinates[1] (i.e. $e_i + jf_i$ at bus i), to enable application to both radial and meshed ADNs. For the sake of illustration and formulation simplicity one assumes: balanced operation, a single transformer at the TSO–DSO interface (see Fig. 1) and RES curtailment is allowed for all objectives.

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[1] The reader is referred to [11] for a thorough study of the pros and cons of polar and rectangular voltage coordinates for AC OPF problems. This reference brings empirical evidence that rectangular coordinates presents slighly better computational performances than polar coordinates.

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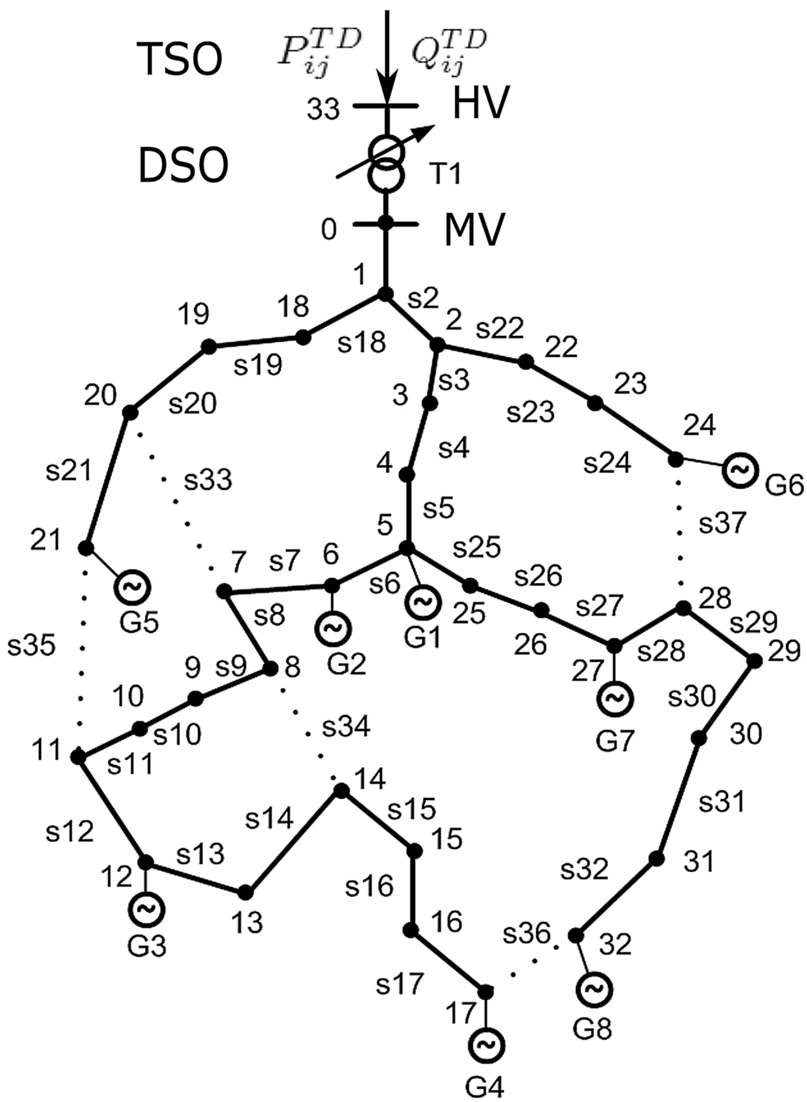

Fig. 1. Modified 34-bus distribution grid and TSO–DSO interface.

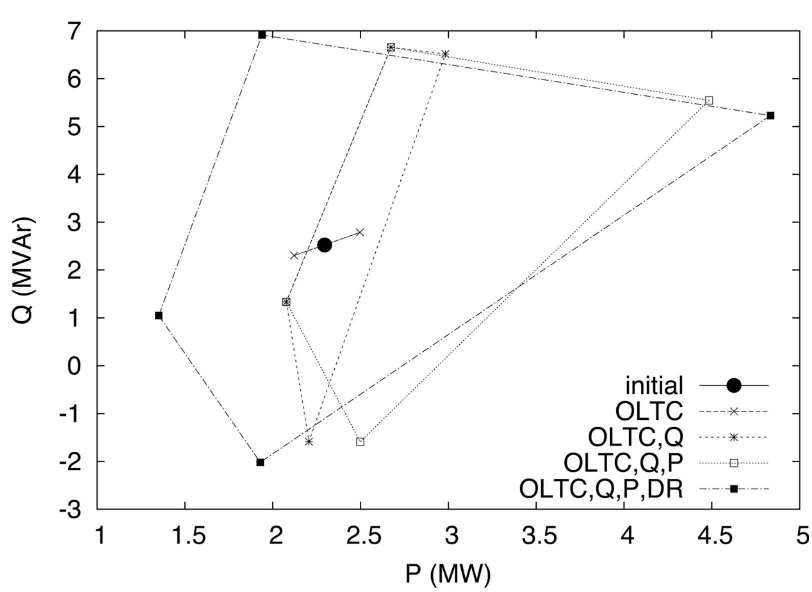

Fig. 2. PQ chart linear approximation relying on the 4 extreme points.