

## Research Article

# Optimization of Distributed Energy Resources in Distribution Networks: Applications of Convex Optimal Power Flow Formulations in Distribution Networks

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The increasing penetration of distributed energy resources (DER) has imposed several challenges in the analysis and operation distribution networks. In the last decade, the implementation of battery energy storage systems (BESS) in electric networks has caught the interest in research since the results have shown multiple positive effects when deployed optimally. However, a complex formulation of the optimization problem regarding DER implementations can easily become nonconvex, thus limiting the scope of the results (quality) and affecting the computational efficiency. In this paper, convex formulations of the optimal power flow (OPF) problem for DER (PV and BESS) installations in San Andres distribution network were implemented to minimize power losses. Four main simulation cases were established covering convex power flow analysis, convex optimal power flow to locate and size dispatchable and nondispatchable DER (PV) with demand and irradiation profiles, and the inclusion of aggregated and distributed PV and BESS systems. The computational realization of those formulations was made with three different software packages: CVX in python, CPLEX, and MATLAB (MATPOWER/PSO). The results show that installing DER capacity (both PV and/or BESS) can substantially improve the power losses in distribution networks, especially if considered distributed instead of aggregated, achieving reductions up to 75% for power losses and up to 57% for conventional generation utilization. Besides power losses, it was observed that optimal DER (PV and BESS) implementations behaved similarly as demand response signals do, potentially increasing economic benefits for DISCOs. In terms of computational efficiency, convex formulations help substantially to reduce computation times, especially if scalability is to be considered when distributed DER installations were studied.

## 1. Introduction

The functioning structure of electricity supply has been undergoing a transformation in the last two decades mainly due to the development of newer energy generation technologies with either significant reductions in associated costs, considerable increases in efficiencies or both [1]. This transformation is based on the decentralization in the direction of the energy flows, in which big and centralized power plants are used to supply entirely the energy through transmission and distribution grids to the consumer, whereas it is nowadays possible to find not only consumers installing generation capacity for self-consumption but also the capacity aggregation from clients in the distribution to supply external demand or to provide

ancillary services. Technically speaking, this paradigm shift takes place mainly in the distribution; therefore, distribution companies (DISCOs) face the challenge of adjusting their operations given new actors, regulations, and technologies, to turn a traditional passive operational framework into a more active one [2].

The role of distributed energy resources (DERs) in these transformations has been primordial, especially with the implementation of photovoltaic (PV) solutions paired with storage (mainly battery energy storage systems (BESS)) to mitigate uncertainty in primary energetic resources [3], thanks to the substantial reduction in costs (around 80% in levelized cost of energy (LCOE) for PV and Lithium-Ion BESS in the period 2010–2018) bringing these technologies not only within

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