Coordinated Optimal Volt/Var Control for Distribution Networks via D-PMUs and EV Chargers by Exploiting the Eigensystem Realization

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***Abstract*—This article proposes a novel optimal hybrid control framework to improve the voltage profile of highly unbalanced Distribution Grids (DGs) by coordinating the injection of reactive power from multiple off-board Electrical Vehicles (EVs) chargers. It exploits the time-synchronized measurements advantages, centralized control, and local controllers embedded into a hierarchical and scalable scheme, coordinated by the distribution system operator (DSO). The proposed framework is aimed to increase the modern electrical networks' flexibility, reliability, and stability. It is powered by the Eigensystem Realization (ER)-based system identification technique, a Linear Quadratic Gaussian (LQG) controller, the Distribution-level Phasor Measurement Units (D-PMUs), and a new aggregator agent that handles the EV chargers power injection to precisely and timely regulate the dynamic voltage response in a sub-area or the entire DG. The robustness and feasibility of the proposal are demonstrated by employing simulated scenarios with unbalanced faults, latency in communications, and highly unbalanced loads conditions on the IEEE 13 and 123 nodes test feeders, compensating the voltage variations accurately in less than 205 ms. The promising outcome of this study suggests a novel application for an emerging measurement-based control system in the operation of modern active DGs.**

***Index Terms*—Distribution grids, Volt/Var control, optimal control, eigensystem realization algorithm, electrical vehicle chargers, distribution phasor measurement units.**

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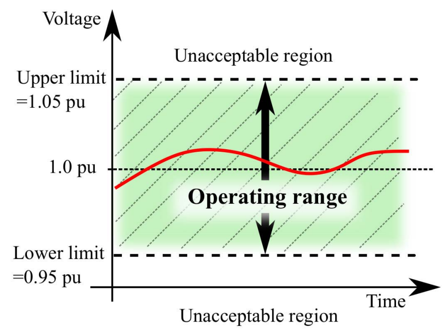

Fig. 1. Regions of operation defined by ANSI C84.1 limits [12].

I. Introduction

THE MASSIVE introduction of Electric Vehicles (EVs) in the transport sector is playing an essential role in reducing greenhouse gas and polluting emissions [1]. This increasing penetration of EVs in distribution systems (DSs) can also contribute to improving the stability and reliability of the modern electrical grids [2]. In turn, EVs chargers working in Vehicle to Grid (V2G) mode can extend the benefits of EVs in electrical power systems by providing ancillary services to the grid, such as voltage support through reactive power injection [3]–[5].

The proliferation of Distributed Energy Resources (DERs) [6], [7], the intermittent and stochastic nature of Renewable Energy Systems (RESs) [8], the connection of non-linear loads with fast dynamics [9], and the growing consumer demand impact the stability and reliability of modern distribution networks by disturbing the voltage profile and challenging the grid operation [10], [11]. This problem can be partially mitigated at the operational planning stage [6]. However, in a short-time (within a millisecond scale), the system may be exposed to unsafe operating states caused by unforeseen events, such as unbalanced failures, rapid load changes, generation losses, among others [8]. Such operating conditions lead the system to abnormal voltage levels that can be tolerated for a short period. Still, it is imperative to bring them within limits quickly established by ANSI C84.1 limits [12], as depicted in Fig. 1.