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Modern transmission expansion planning under the energy transition: Insights from Latin America and the Caribbean

M.S. Gómez Pérez; A. Ramos Galán; S. Lumbreras Sancho; L. Olmos Camacho; P. Mastropietro

Abstract-

Limited transmission capacity remains a critical bottleneck for renewable energy integration worldwide, demanding highly proactive and flexible approaches to Transmission Expansion Planning (TEP). Moving beyond descriptive literature reviews, this paper proposes a mathematically grounded diagnostic framework to evaluate the institutional and methodological maturity of modern TEP practices. Utilizing a 3-level ordinal scale, we systematically assess how uncertainty, operational constraints, and Grid-Enhancing Technologies (GETs) are modeled within the optimization stages of five Latin America and the Caribbean (LAC) countries. This regional diagnostic reveals structural gaps, most notably the absence of endogenous mathematical integration of GETs within current planning tools. To substantiate this finding, a heuristic sensitivity analysis on a transmission corridor in Colombia demonstrates that Dynamic Line Rating (DLR) can provide a 36 % admissible thermal headroom above the static rating, covering 97 % of the simulated N–1 capacity shortfall—yet the remaining deficit confirms that endogenous co-optimisation is structurally required. By bridging the disconnect between advanced theoretical formulations and real-world operational realities, this work provides a concrete methodological roadmap to accelerate resilient and coordinated grid modernization.

Index Terms- Transmission expansion planning; Grid-enhancing technologies; Uncertainty modeling; Latin America and the Caribbean

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