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Assessing the impact of renewable energy penetration and geographical allocation on transmission expansion cost: a comparative analysis of two large-scale systems

L. Herding; M. Rivier Abbad; R. Cossent Arín; S. Bañales

Abstract-

Ambitious renewable energy development plans require an efficient electricity grid connection of massive generation capacity. Significant transmission network investments are considered necessary to support the energy transition. This paper analyses the transmission grid reinforcement requirements of two large-scale electricity systems with notably different geographical distributions of renewable resource availability and load density. The results indicate that optimal transmission expansion accounts for less than 10% of total annualised system investment (generation capacity + transmission grid). This is true even in transmission systems with significant existing bottlenecks. The study includes a sensitivity analysis of the location of renewable energy source (RES) capacity. The sensitivities examine the impact of varying the concentration of RES in resource-rich areas, as well as the proportion of RES capacity connected at the distribution level. Both sensitivities are evaluated over a common base case scenario. The results show that a higher concentration of RES capacity in resource-rich network zones can more than double the optimal transmission expansion requirements. In contrast, the implementation of distributed generation (DG) leads to the allocation of generation closer to demand centres, resulting in transmission grid savings of up to 30%. These effects are more pronounced in networks where RES capacity is located further away from major demand centres. This is because existing bottlenecks are exacerbated by higher RES concentration and relieved as the share of DG increases.

Index Terms- Energy transition; Power system decarbonisation; Distributed generation; Transmission expansion planning; Power system planning

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