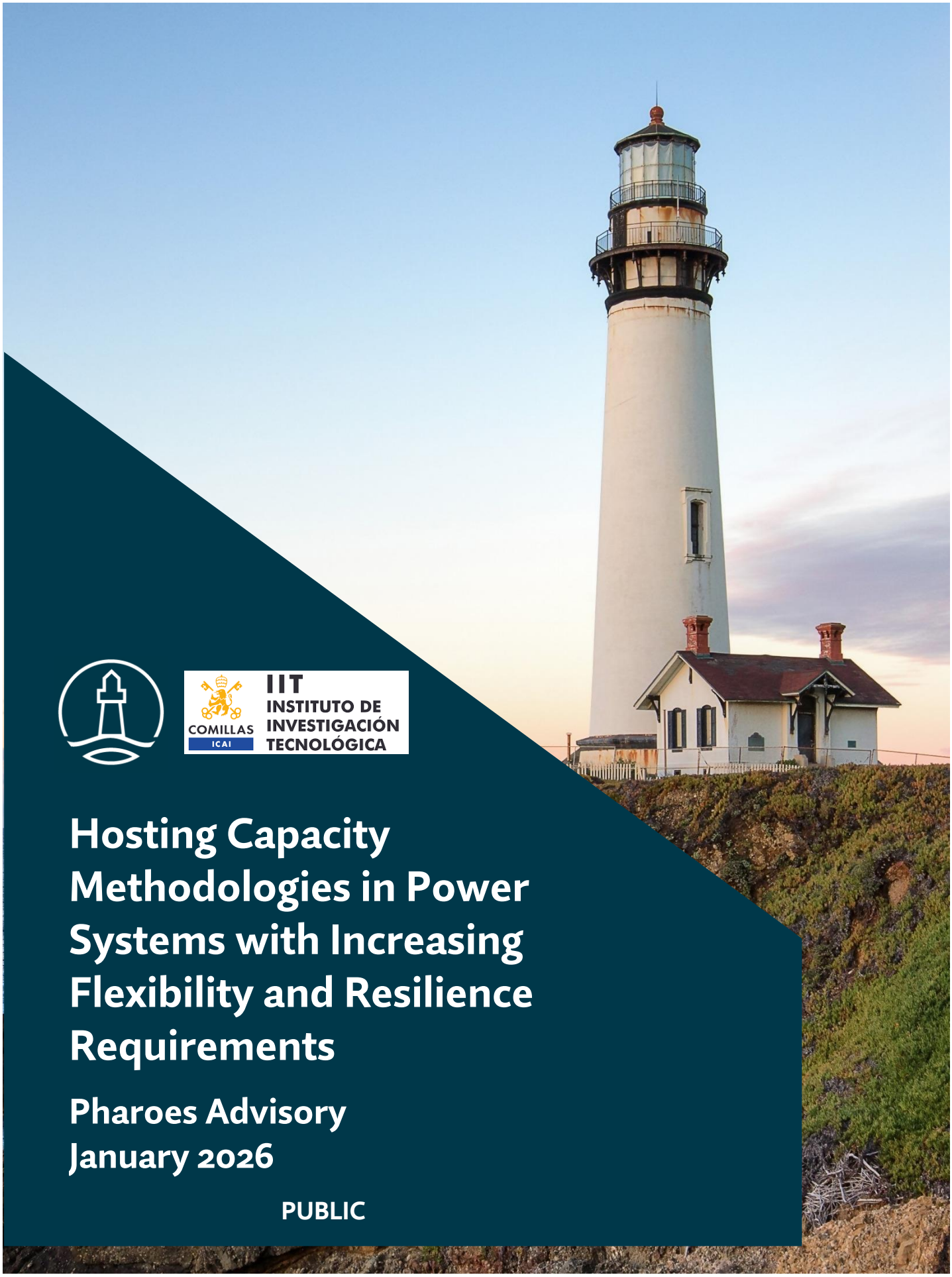

# Hosting Capacity Methodologies in Power Systems with Increasing Flexibility and Resilience Requirements

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# Introduction: the growing relevance of hosting capacity in a context of network saturation

In recent years, the concept of **hosting capacity (HC)** understood as the maximum amount of new distributed generation, storage or intensive loads that a power network can accommodate without the immediate need for reinforcements, has gained increasing importance due to the saturation of certain network areas and the growing difficulty of reaching agreements on network tariffs.

This rising interest is driven by several simultaneous trends that are putting significant pressure on transmission and distribution networks in many countries. These include the accelerated deployment of distributed renewable generation, the growing electrification of sectors such as mobility and heating, and the development of new infrastructures linked to the digital economy, particularly data centers. In addition, there are increasing difficulties in obtaining permits for new lines and greater social sensitivity to the visual and environmental impact of new electrical infrastructure.

In this context, obtaining grid access and connection permits is becoming increasingly challenging. In Spain, there are already areas with limited or exhausted capacity, which constrains the development of new renewable projects as well as the expansion of high-impact loads such as data centers.

This growing pressure on infrastructure, combined with the availability of flexibility measures such as batteries and electric vehicles, means that hosting capacity analyses can no longer rely solely on static scenarios. It is necessary to explicitly incorporate the potential of flexible resources and to capture the network response to extreme events and low-probability but high-impact situations.

# Hosting capacity calculation methodologies

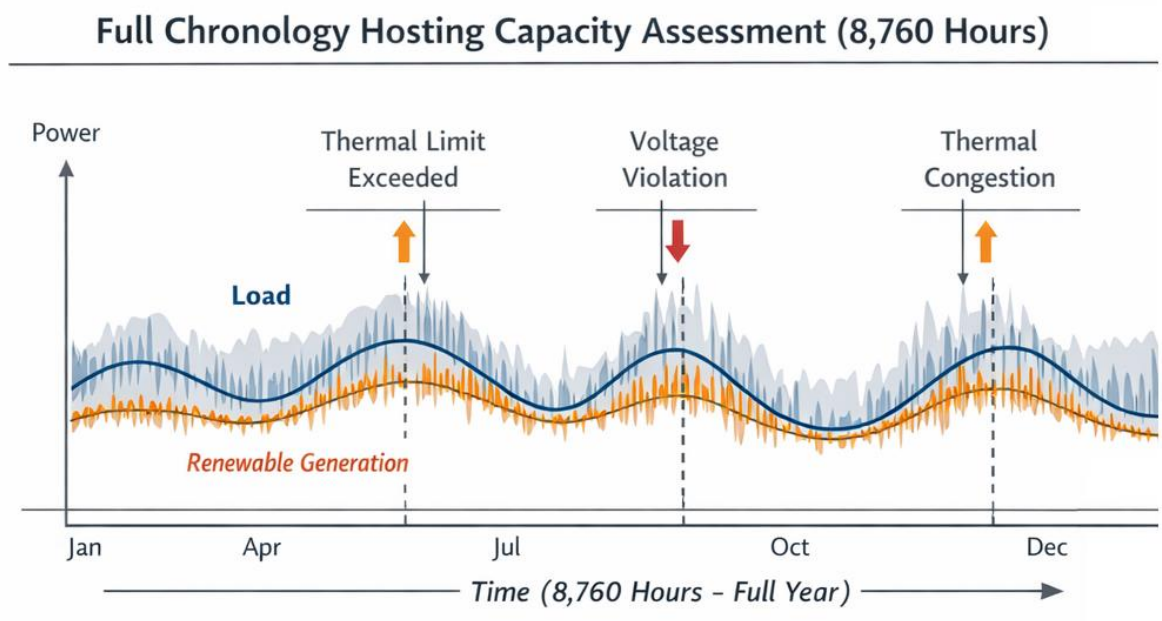
This section presents the main methodologies used for hosting capacity assessment, together with their key characteristics and limitations.

**Deterministic methods**

Deterministic methods evaluate the network under fixed operating conditions and include two main variants:

- **Typical scenarios**, which consider specific operating points such as peak demand, minimum demand, or maximum photovoltaic production.
- **Full chronology**, which analyzes all 8,760 hours of the year.

Their main advantage is transparency, as they are easy to understand and implement. Typical-scenario approaches also require limited data and enable fast analyses. However, depending on the selection of scenarios, they may lead to overly conservative or excessively optimistic estimates. Full chronological approaches provide a more representative characterization but require detailed hourly data and significantly higher computational effort.



### Stochastic or probabilistic methods

This approach incorporates the variability of generation and demand using techniques such as Monte Carlo simulations or probabilistic distribution models. It allows hosting capacity to be estimated with a given confidence level and is particularly useful in networks with high renewable penetration, where temporal variability has a significant impact.

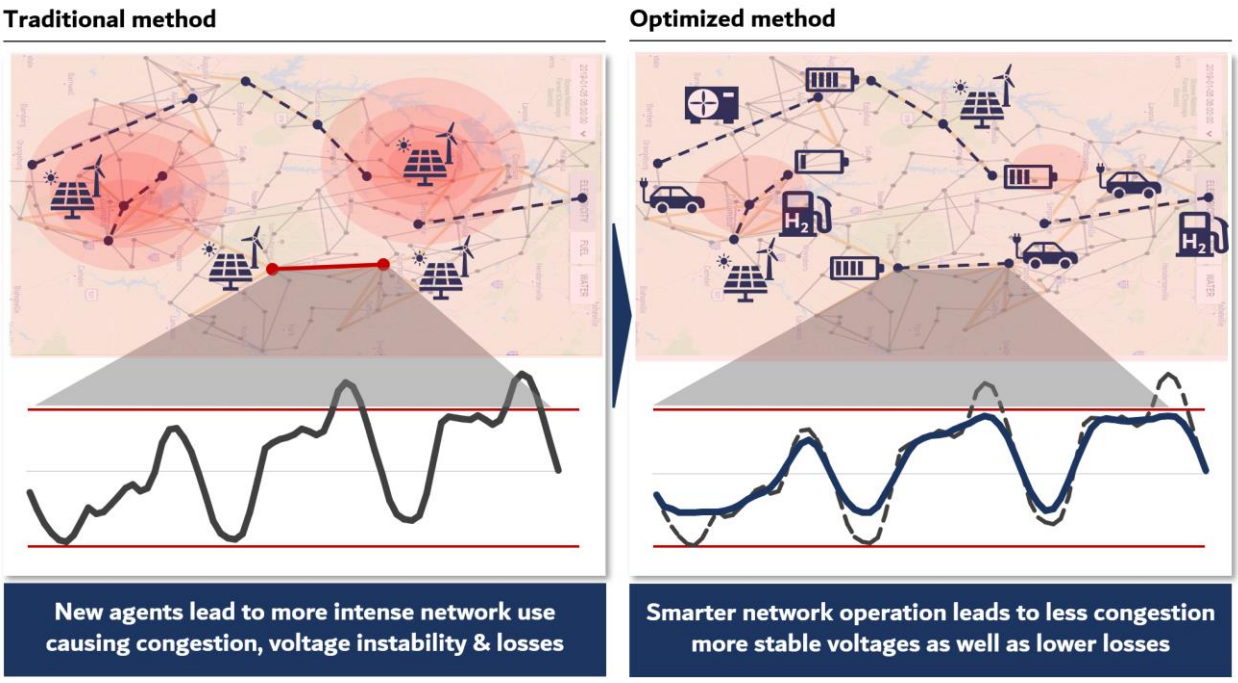
Its main limitations are the need for large and reliable statistical datasets and the fact that results can sometimes be difficult to communicate with non-specialist stakeholders.

### Iterative or incremental methods

These methods progressively increase injected or demanded power at one or more nodes until a technical constraint is violated. This approach helps identify critical nodes and is frequently used in operational studies by network operators. Its main drawback is that it may ignore complex interactions or alternative operational solutions that could emerge in real operation but are not captured in such simplified analyses.

### Optimization-based methods (OPF) with flexibility and active control

These methods formulate hosting capacity as an optimization problem, subjecting system operation to thermal, voltage, short-circuit, stability and protection coordination constraints. They allow the explicit modeling of advanced voltage control, energy storage systems, active demand management, controlled distributed resources, network reconfiguration and advanced grid devices.



This is the most comprehensive approach, as it identifies the maximum hosting capacity achievable under technically feasible operation. Its main challenge lies in computational complexity, especially for multi-period studies, AC OPF formulations, and when resilience and contingency response are explicitly considered.

## Flexibility & resilience: new framework for hosting capacity

Traditional hosting capacity analyses were based on the assumption of a largely passive network. The massive deployment of flexible resources is changing this paradigm and opening the door to significantly higher integration capacities.

**Battery energy storage systems (BESS) as a structural element**

Energy storage systems are not limited to energy arbitrage. In hosting capacity studies, they can help manage congestion, smooth ramps, provide reactive power support and contribute to system response under extreme events. In distribution networks with thermal or voltage constraints, their role can be decisive in enabling additional photovoltaic generation or new intensive loads.

**Electric vehicles as distributed flexible resources**

Electric vehicles introduce significant new demand but can also become a powerful flexibility tool through smart charging strategies. In more advanced stages, grid injection under vehicle-to-grid (V2G) schemes could even improve system operation during critical periods.

**Grid-forming inverters in photovoltaic plants and data centers**

The evolution towards grid-forming inverters enables the provision of stability services, voltage support and increased robustness against disturbances. Some data centers already have UPS infrastructure capable of operating in advanced modes, enhancing their ability to support the grid during extreme situations.

**Flexibility and resilience in an integrated analysis**

Modern hosting capacity studies must integrate these flexibility sources simultaneously and assess their ability to enhance network resilience. This allows not only the evaluation of how much distributed generation or load can be integrated, but also how the system will behave under contingencies and unforeseen events.

# Conclusions & capabilities of IIT-Comillas and Pharoes

The energy transition and digitalization are increasing pressure on power networks, which have become a critical factor for competitiveness and economic development. In this context, having rigorous hosting capacity analyses adapted to current technological realities is essential to guide investment, operational and regulatory decisions.

The team at the **IIT of Comillas Pontifical University**, together with its technology partner **Pharoes**, has the experience and tools required to carry out these studies with an approach aligned with today's challenges. The combination of detailed network modeling capabilities, advanced optimization algorithms, extensive international experience and proprietary accelerated computing technology enables the delivery of robust and actionable analyses for operators, regulators and market participants.

**About the authors**

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