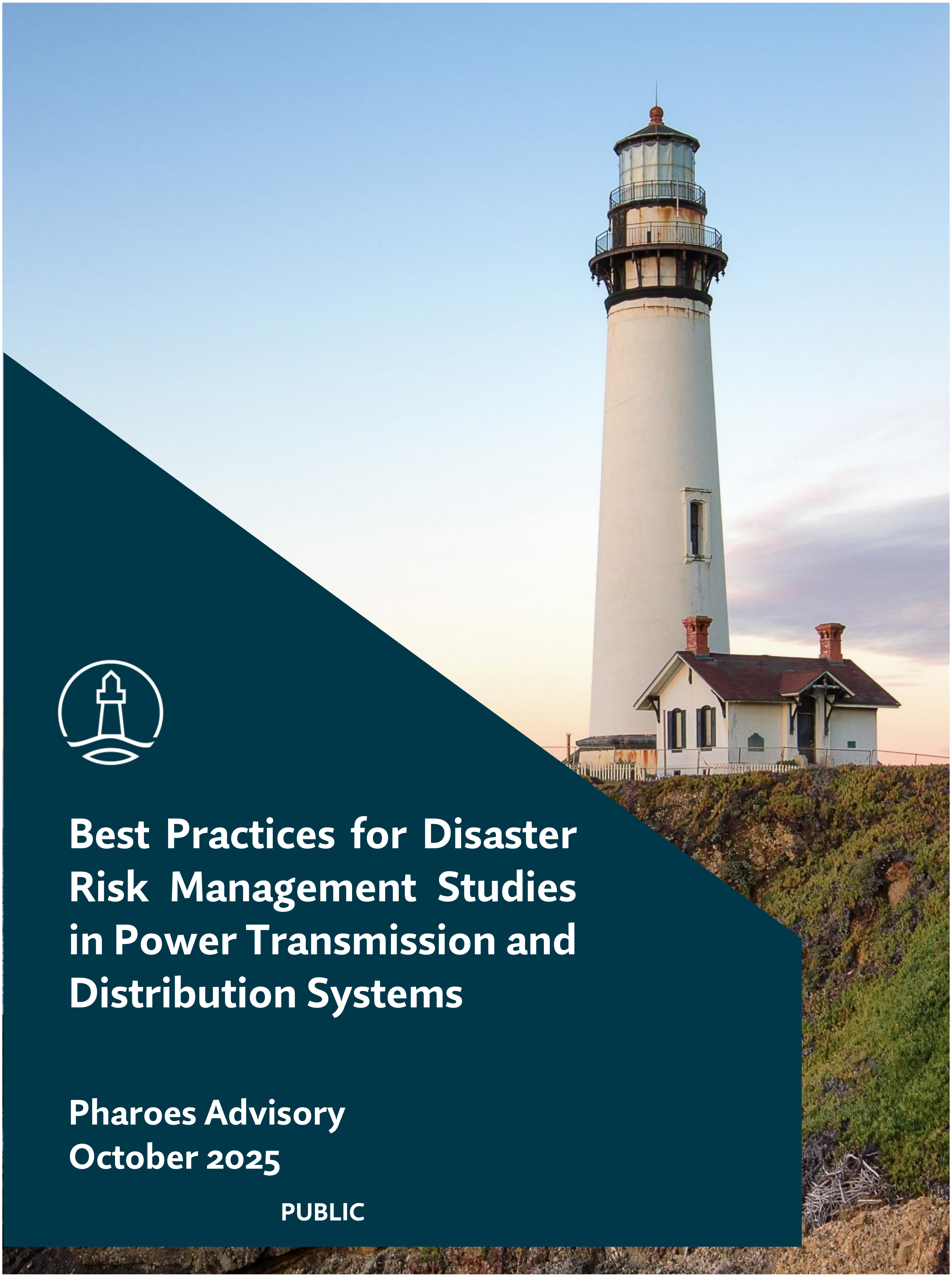

Best Practices for Disaster Risk Management Studies in Power Transmission and Distribution Systems

Pharoes Advisory

October 2025

PUBLIC

Purpose and scope of Disaster Risk Management studies in the power sector

Disaster Risk Management studies in the power sector are intended to support informed decision making related to planning, investment, and operation of transmission and distribution systems under conditions of uncertainty. Their primary objective is not the elimination of risk, but the systematic reduction of the likelihood and consequences of disruptive events that can affect electricity supply, public safety, and economic activity. These studies should explicitly link technical analysis with broader objectives such as continuity of service, protection of critical infrastructure, and resilience of essential public services.

A clear definition of scope is essential. This includes specifying whether the study covers transmission systems, distribution systems, or both, and recognizing the fundamentally different risk profiles and operational characteristics of each. Transmission systems tend to be exposed to low frequency but high impact events with system wide consequences, while distribution systems are more frequently affected by localized disruptions with direct impacts on customers. The geographic boundaries of the study, the interfaces with neighboring systems, and the relevant planning horizon should be clearly stated and aligned with asset lifetimes and investment cycles.

Hazard identification and characterization

Effective Disaster Risk Management begins with a comprehensive identification and characterization of hazards that may affect the power system. This process should adopt a multi hazard perspective, considering hydrometeorological, geological, and climate driven threats, as well as both sudden extreme events and slower onset stressors. Hazard assessment should reflect regional and local conditions rather than relying solely on national level indicators, as exposure and intensity can vary significantly within a single system.

Hazard data should be selected with spatial and temporal resolution appropriate to the network under study, taking into account the topology of transmission corridors and the granularity of distribution networks. In addition to assessing the likelihood and intensity of individual hazards, studies should consider compound and cascading events, where multiple hazards occur simultaneously or in sequence. Uncertainty in hazard data and projections should be explicitly documented, as it directly affects the interpretation of results and subsequent decision making.

Asset exposure and vulnerability assessment

A robust assessment of exposure and vulnerability requires a complete and georeferenced inventory of transmission and distribution assets. Assets should be classified according to their function, voltage level, and role in system operation, with particular attention given to those whose failure would result in larger scale outages with prolonged restoration times. Both structural and functional vulnerabilities should be evaluated, considering design standards, age, condition, and maintenance practices.

Vulnerability assessment should distinguish between different failure mechanisms associated with specific hazards, such as mechanical damage from high winds, inundation of substations due to flooding, or thermal stress during extreme temperatures. Functional aspects such as protection systems, control equipment, and communications infrastructure are often critical contributors to system performance during disasters and should be explicitly included. Dependencies on external infrastructure, including transportation, telecommunications, and fuel supply, should be considered, as they affect restoration.

System level risk and impact analysis

While asset level assessments provide important insights, Disaster Risk Management studies should ultimately focus on system level impacts. This involves evaluating how asset failures affect power flows, system stability, and the ability to supply demand. The analysis should quantify consequences in terms of outage duration, unserved energy, and the number and type of customers affected, where data and models allow.

Credible extreme scenarios should be examined in addition to expected or average conditions, particularly for events with low probability but severe consequences. Seasonal operating conditions, such as peak demand periods, should be considered, as they can amplify the impacts of asset outages. The analysis should also reflect the role of operator actions, protection schemes, and system controls, avoiding assumptions of perfect system response or immediate restoration.

Transmission and distribution specific considerations

Transmission and distribution systems require differentiated analytical approaches within Disaster Risk Management studies. For transmission systems, the focus should be on corridor level exposure, redundancy, and system separability. Attention should be given to substations that act as critical nodes or single points of failure. The ability of the system to reroute power, operate in islanded configurations, or recover from widespread disturbances should be assessed, and disaster risk considerations should be integrated into long term transmission expansion planning.

For distribution systems, the analysis should emphasize feeder topology, customer density, and the proximity of assets to hazard prone areas. Distribution networks are often the primary source of customer outages and therefore require detailed assessment of assets supplying critical services such as hospitals, water systems, and telecommunications. Vegetation management practices, right of way conditions, and differences between urban, peri urban, and rural networks should be explicitly addressed.

Integration of climate change considerations

Climate change should be treated as a factor that modifies the characteristics of existing hazards over time rather than as a separate analytical component. Disaster Risk Management studies should use climate scenarios consistently across all relevant hazards, while avoiding an over-reliance on precise long-term projections that may carry significant uncertainty. The emphasis should be on identifying solutions that remain effective across a range of plausible future conditions.

Where possible, studies should identify thresholds beyond which current design standards and operating practices may no longer be adequate. Assumptions should be aligned with national climate strategies and adaptation plans where these exist, ensuring coherence between sector specific analyses and broader policy frameworks.

Identification of risk mitigation and resilience measures

The identification of mitigation and resilience measures should result in a diversified portfolio of options addressing different drivers of risk. Measures may include structural reinforcement of assets, reconfiguration of network topology, improvements in operational practices, and enhanced emergency preparedness. Nonstructural and nature-based solutions should be considered where appropriate, particularly when they offer cost effective or complementary risk reduction benefits.

Each measure should be evaluated not only for its effectiveness in reducing risk, but also for its feasibility given institutional capacity, technical complexity, and implementation timelines. Care should be taken to avoid an exclusive focus on capital intensive solutions, and to identify potential unintended consequences or maladaptation risks associated with proposed interventions.

Economic and financial assessment

Economic and financial assessment is essential for prioritizing resilience investments. Benefits should be estimated in terms of avoided damages, reduced outage duration, and improved continuity of service, particularly for critical customers. Valuation of reliability improvements should be based on consistent assumptions and clearly documented methodologies.

Given the inherent uncertainty associated with disaster risks, sensitivity analysis should be used to test the robustness of results under different assumptions. A clear distinction should be made between economic efficiency from a societal perspective and financial affordability from the utility perspective. The assessment should align with the appraisal requirements of financing institutions and avoid overstating the precision of long-term benefit estimates.

Prioritization and phasing of actions

The translation of analytical results into actionable recommendations requires transparent and structured prioritization. Measures should be ranked based on clearly defined criteria that balance risk reduction benefits, costs, implementation complexity, and social considerations. Equity impacts and the protection of vulnerable populations should be explicitly considered in prioritization decisions.

Recommended actions should be phased over time, distinguishing between short-, medium-, and long-term interventions. Responsibilities for implementation and monitoring should be clearly assigned, and proposed actions should be linked to realistic funding sources and institutional arrangements.

Institutional and regulatory aspects

Institutional and regulatory conditions play a critical role in the effectiveness of Disaster Risk Management. Studies should review existing governance arrangements for disaster preparedness, response, and recovery, and clarify the roles of utilities, regulators, and emergency management agencies. Regulatory frameworks should be assessed to determine whether they provide appropriate incentives for investment in resilience.

Gaps in procedures, coordination mechanisms, or staff capacity should be identified, and opportunities for integrating disaster risk considerations into routine asset management and maintenance processes should be explored. Disaster Risk Management should be treated as an ongoing institutional function rather than a onetime analytical exercise.

Data, modeling, and analytical tools

The choice of data, models, and tools has a significant influence on the quality and credibility of Disaster Risk Management studies. Analytical approaches should reflect actual network topology, operational constraints, and the temporal dynamics of hazardous events. Assumptions and limitations should be documented clearly to ensure transparency and facilitate informed interpretation of results.

Models and databases should be designed to be updated as new information becomes available, supporting iterative improvement over time. A balance should be struck between analytical sophistication and practical usability, ensuring that tools can be understood and applied by utility staff and decision makers.

Stakeholder engagement and communication

Meaningful stakeholder engagement is essential throughout the Disaster Risk Management process. System operators, maintenance staff, and local experts should be involved from early stages to ensure that analyses reflect operational realities and local knowledge. Results should be communicated in a manner that supports decision making rather than overwhelming stakeholders with technical detail.

Uncertainty should be communicated clearly and honestly, and outputs should be tailored to the needs of different audiences, including utility management, regulators, and policy makers. Effective communication helps ensure that Disaster Risk Management studies translate into concrete actions and sustained institutional commitment.

Monitoring, review, and continuous improvement

Disaster Risk Management is inherently dynamic and requires ongoing monitoring and periodic review. Studies should define indicators to track progress in risk reduction and system resilience, and incorporate lessons learned from actual disruptive events. Assessments should be updated to reflect changes in system configuration, asset condition, and hazard information.

Alignment with investment planning and regulatory cycles can help institutionalize continuous improvement. Over time, Disaster Risk Management should evolve from a project activity into a core capability within utility planning and operational practices.

About the authors

This article was written by Diego Luca de Tena, Managing Director of Pharoes, based in Madrid. The author would like to thank Dr. Sonu Khanal from Hydrominds for his careful review of the manuscript and for his valuable technical insights and comments.