GRIDCO
Empowering Odisha

CDRI
Coalition for Disaster Resilient Infrastructure

Towards Resilient Power Infrastructure in Odisha

Component I

Disaster Resilient Power Systems for Odisha

PricewaterhouseCoopers (PwC)

Foreword

Power infrastructure and a stable electricity connection is an essential enabler of development. It supports homes, businesses, schools, hospitals, and the supply of other utilities. The introduction of smart grid technologies, bolstering renewable energy sources, and enhancing load efficiency is imperative for achieving global climate commitments.

Escalating climate risks present a challenge to this essential infrastructure and its interconnected systems. Power infrastructure in coastal regions is particularly vulnerable given the magnitude of climate intensified extreme weather events in these regions.

India has a coastline stretching over 7,500 kilometres. Its coastal areas are home to more than 260 million inhabitants. Cyclones like Fani (2019), Gaja (2018), and Hudhud (2014), which were accompanied by severe flooding, caused extensive damage to lives and livelihoods across the coastal states of Odisha, Andhra Pradesh, Tamil Nadu, and Kerala.

In response, India has become a leader in building resilience in coastal areas. Improved disaster preparedness, early warning systems, and well-executed evacuation strategies, have played a pivotal role in safeguarding vulnerable populations.

Odisha's experiences in recovering quickly from various disaster events offer compelling evidence for the development of resilient power infrastructure. The state became the first state in India to establish a disaster management authority in 1999 after the Super Cyclone, even before the establishment of the National Disaster Management Authority (NDMA) in 2005. It was also the first Indian state to create an early warning system for disseminating critical disaster-related information to the very last mile. Odisha State Disaster Management Authority has utilized the best technical expertise for building over 800 multi-purpose cyclone shelters together with evacuation roads along the state's entire coastline. Odisha's success in bringing down the casualty to double digits and putting in place robust mechanisms for risk-informed decision-making is a significant achievement.

In support of these efforts, recognizing the particular importance of power infrastructure, and to develop evidence that can be shared with other vulnerable regions, CDRI's study "Disaster Resilient Power Systems for Odisha" has aimed at strengthening the power infrastructure.

This work has identified key challenges and best practices within the Transmission and Distribution (T&D) sector at the subnational level. To understand vulnerabilities related to the T&D infrastructure system along its entire 480 km of coastline, 16 indicators were identified ranging from commissioning year to asset failure history. Recommended actions, including investment options to strengthen resilience of the T&D infrastructure, were prepared accordingly. The study serves as a vital resource for stakeholders in the power sector.

On behalf of CDRI, I express sincere gratitude to all stakeholders from the Government of Odisha, including GRIDCO Ltd, for their invaluable contributions to the report's methodology and policy recommendations for the short, medium, and long term. I would also like to extend my sincere appreciation for NDMA's support throughout the entire effort. Collaboration with Taru Leading Edge, Power Research and Development Consultants (PRDC), and KPMG - India has been instrumental in preparing this report, which serves as an indispensable tool for policymakers, practitioners, manufacturers, and other stakeholders in the power sector.

CDRI believes that the resilience of the power sector to extreme weather events is pivotal in safeguarding the lives and livelihoods of millions, particularly those in vulnerable regions. We are committed to take the lessons learned in Odisha and expand similar work to support coastal regions around the world.

Amit Prothi
Director General, CDRI
New Delhi, India, June 2024

Foreword

Global energy consumption is steadily increasing annually, with an anticipated 48 percent growth over the next two decades, driven by the exponential rise in global population. In the face of escalating challenges posed by climate change, ensuring resilience in energy systems is imperative for overall development. Given the historical impact of extreme weather events on the state of Odisha, particularly the Transmission and Distribution (T&D) segment, the state has demonstrated remarkable resilience. It has rebounded and recovered by developing innovative adaptation and mitigation strategies in response to periodically changing wind speeds and the looming risk of climate change.

Understanding the socio-economic impact and losses in this regard, this study serves as an essential tool and a precursor at the sub-national, national, and global levels for coastal regions and regions with similar geographies. It provides insights into strategies that can be replicated not only for risk identification and estimation but also for capacity building, knowledge management, and financial preparedness.

This initiative aims to evaluate the climate resilience of Odisha's power infrastructure in a unique way. It will not only help in reshaping the policy landscape and risk-based governance for coastal regions but also provide valuable insights for energy sector practitioners, Original Equipment Manufacturers (OEMs), and regulators. The report details individual unit-level assets, their vulnerabilities, and offers investment options on how to build more resilient transmission and distribution assets. By setting a new standard for resilience initiatives, the study is expected to significantly influence the development of robust and adaptive energy systems, ensuring a sustainable and secure future for all.

I extend my appreciation to the Coalition for Disaster Resilient Infrastructure (CDRI) and the project stakeholders for this collaborative effort, which will help enhance the reliability and resilience of the state's power infrastructure. I strongly believe that the report will serve as a benchmark in climate-proofing of energy infrastructure in Odisha.

Principal Secretary to Government
Energy Department,
Government of Odisha

Preface

In October 1999, a super cyclone struck the Indian state of Odisha, resulting in substantial economic and social losses.

From a human death count of 10,000 to widespread destruction of critical infrastructure (including houses and public buildings), the cyclonic winds and rain (gusting with a speed of over 250 km/h) left the state with nothing but submerged crops and loss of lives.

The super cyclone served as another wake-up call for disaster management in India, leading to the eventual adoption of the Disaster Management Act in 2005. The Act established the National Disaster Management Authority (NDMA), which is responsible for setting policies, plans and guidelines for disaster management in India.
Subsequently, the central and state governments took measures to minimize social and economic losses caused by disasters. The Act also paved the way for the formation of the National Disaster Response Force (NDRF), which is considered to be the largest specialized disaster response force in the world.

Since the turn of the century, concerted efforts by national and state-level governments, as well as non-governmental organizations, have saved countless lives in the face of catastrophes by using advanced early warning systems and extensive public messaging campaigns. This has been coupled with disaster preparedness measures such as evacuations to cyclone shelters. In May 2019, similar efforts resulted in a significant reduction in the death toll during Cyclone Fani.

However, economic losses due to disasters have significantly increased. For example, the damages caused by the Super Cyclone (1999) caused damages to Odisha's power lines and transformers worth US$ 60 million. Two decades later, this rose to over US$ 1.2 billion during Cyclone Fani (2019).

According to the World Meteorological Organization (WMO), while improved early warnings and disaster management systems helped decrease the number of deaths around the world by almost three-fold between 1970 and 2019, economic losses increased by seven times during the same period.

This could be attributed to the increase in population in hazardous regions, thereby putting more buildings and infrastructure in a vulnerable position. As less vulnerable regions become more populated, people are pushed into areas more prone to risks. This relocation threatens both residents and supporting infrastructure, despite risk-reduction regulations and land zoning in place.

Another factor contributing to the rise in economic losses is the changing climate patterns. This indicates that the existing infrastructure designs are not resilient enough to tackle the severity and growing frequency of cyclones over the years. For instance, in 2021, the Intergovernmental Panel on Climate Change (IPCC) noted that scientists were observing 'widespread, rapid and intensifying' changes to the Earth's climate in every region and across the whole climate system.

This will lead to intense changes in weather patterns, including more intense precipitation. It is worth noting that since 2010, Odisha alone has been hit by five high-intensity cyclones, increasing the net economic losses borne by the state due to the destruction of homes, power lines, roads and telecom infrastructure.

Extreme weather events not only damage infrastructure but also bring regular life to a standstill. Apart from disruptions to economic and industrial activities, damages to power infrastructure can have multiple cascading effects on other infrastructure and public services such as transportation, telecom, water supply, medical and healthcare and banking services, limiting people's access to critical resources required to recoup and recover. These disruptions have been known to have caused severe, long-lasting impacts across economies.

This report is an initiative of the Coalition for Disaster Resilient Infrastructure (CDRI), an international partnership of national governments, United Nations agencies, multilateral development banks and other stakeholders. It uses the case of Cyclone Fani to assess strategies for making power infrastructure more resilient to disasters in coastal regions similar to Odisha. The report will primarily focus on 'softer' aspects such as skill building, construction quality, operation and maintenance, better planning and training.

As per CDRI's study, strengthening infrastructure could take years and require significant investment. However, such a journey promises long-term benefits attributable to improved and well-implemented systems and processes. Furthermore, following standard operating procedures, having well-developed and up-to-date contingency plans and resources, and sharing clear and regular updates with people could go a long way in mitigating the magnitude of damage and suffering inflicted upon economies due to a disaster.

The first phase of the study focuses on disaster preparedness and response. It highlights simple processes like setting up a central 'control room' to manage post-disaster operations, maintaining a public webpage for power supply updates and emergency contact information, and conducting regular drills and training of all staff members, which could assist in significantly reducing recovery times. Such measures, which also have a relatively lower cost, can be implemented immediately and will significantly enhance the overall resilience of the power infrastructure in the state.

Key learnings from the study were presented at a national-level meeting to Shri R.K. Singh, Minister of Power, New and Renewable Energy, Government of India, which led to the development of advisories for power departments in cyclone-affected states across India.

The second phase of the CDRI study will involve a detailed assessment of disaster risks to identify 'hardware' improvements along with policies, processes and finance required to foster long-term resilience for Odisha's power infrastructure.

Acknowledgements

This report is part of the Coalition for Disaster Resilient Infrastructure's (CDRI) Power Sector Resilience Programme and is a key output of a comprehensive, phased study aimed at strengthening the resilience of the power sector in Odisha, India.

The CDRI team, in partnership with the Odisha State Disaster Management Authority (OSDMA), led the preparation of this report.

It was drafted by the technical consulting team from PricewaterhouseCoopers (PwC) under the guidance of CDRI and OSDMA.

The proactive support from the OSDMA team helped make this report a comprehensive document with practical information about resilient power infrastructure in Odisha and India.

The team acknowledges the strategic guidance, operational support and encouragement provided by Kamal Kishore (Assistant Secretary-General and Special Representative of the Secretary-General for Disaster Risk Reduction, United Nations Office for Disaster Risk Reduction), Amit Prothi (Director General, CDRI) and Odisha Power Transmission Corporation Limited, Odisha Discoms and OSDMA.

The team would also like to acknowledge the contributions and valuable technical feedback of several internal and external peer reviewers.

We thank Rajita Agarwal and Deepak Rawat of CDRI for providing excellent administrative support throughout the project.

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Abbreviations

ACE	Atlantic City Electric
AMI	Advanced Metering Infrastructure
APPA	American Public Power Association
BAU	Business as Usual
BI	Business Intelligence
CAT	Catastrophic
CCA	Climate Change Adaptation
CDRI	Coalition for Disaster Resilient Infrastructure
CESU	Central Electricity Supply, Company of Odisha Ltd.
CFC	Chlorofluorocarbons
CKT KMS	Circuit kilometres
COP	Conference of Parties
CPP	Captive Power Plant
CPSU	Central Public Sector Undertaking
DDO	Deferred Draw down Option
DEOC	District Emergency Operation Centre
DG	Diesel Generator Set
DGPS	Differential Global Positioning System
DISCOM	Distribution Company
DM	Disaster Management
DPL	Development Policy Loan
DRC	Disaster Response Centre
DRI	Disaster Risk Index
DRPS	Disaster Resilient Power System
DRR	Disaster Risk Reduction
DTR/DT	Distribution Transformer
EHV	Extra High Voltage
EICC	Energy Investment Coordinating Council
ERS	Emergency Restoration System
FEMA	Federal Emergency Management Agenc
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System

Abbreviations

GRIDCO	Grid Corporation of Odisha Limited
HCFC	Hydrochlorofluorocarbons
HT	High Tension
IDA	International Development Association
IMD	India Meteorological Department
IPP	Independent Power Producer
ISGS	Inter-State Generating Station
KSEB	Kerala State Electricity Board
LT	Low Tension
LTCT	Low Tension Current Transformer
MDG	Millennium Development Goal
MoP	Ministry of Power
MVA	Mega Volt Amperes
MW	Mega Watts
NDMA	National Disaster Management Authority
NLDC	National Load Dispatch Centre
NORTHCO	Northern Electricity Supply Company of Odisha Limited
NTPC	National Thermal Power Corporation
NYSEG	New York State Electric and Gas Corp
ODRAF	Odisha Disaster Rapid Action Force
ODSSP	Odisha Distribution System Strengthening Programme
OERC	Odisha Electricity Regulatory Commission
OHPC	Odisha Hydro Power Corporation Limited
OMS	Outage Management System
OPGC	Odisha Power Generation Corporation
OPTCL	Odisha Power Transmission Corporation Limited
OPGW	Optical Ground Wire
OSDMA	Odisha State Disaster Management Authority
PEPCO	Potomac Electric Power Company
PGCIL	POWERGRID Corporation of India Limited
RCP	Resiliency Compliance Plan
RG&E	Rochester Gas and Electric
RLDC	Regional Load Dispatch Centre

Abbreviations

SEOC	State Emergency Operation Centre
SMUG	Seriousness, Manageability, Urgency and Growth
SOP	Standard Operating Procedure
SOUTHCO	State Public Sector Undertaking
SPSU	State Public Sector Undertaking
TPCODL	Tata Power Central Odisha Distribution Limited
TPNODL	Tata Power Northern Odisha Distribution Limited
TPSODL	Tata Power Southern Odisha Distribution Limited
TPWODL	Tata Power Western Odisha Distribution Limited
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNFCCC	United Nations Framework Convention on Climate Change
WESCO	Western Electricity Supply Company of Odisha Limited

Executive Summary

Amid rapid urbanization and unceasing technological innovations, protecting existing and new infrastructure in the face of climate change becomes a prerequisite for achieving optimal socio-economic progress in developing nations. Natural catastrophes disrupt the normal functioning of communities, leading to extensive losses for physical, administrative and social infrastructure. When planning for disaster-resilient infrastructure, it is essential to prioritize critical infrastructure such as power, water and sanitation, telecommunication, transport and healthcare centres. Among these key priority areas, the power sector creates numerous interlinkages for all kinds of asset classes in an economy. From uninterrupted medical services to numerous household services, the power sector informs the everyday life of citizens, enabling them to utilize resources effectively and efficiently.

Given the vital role played by the power sector in sustainable development, there is a clear need to develop robust state-level infrastructure strategies that will facilitate the integration of power infrastructure resilience into the broader national development planning process. While it will take time to fully integrate resilience at the national level, an immediate step is to focus on the most vulnerable regions that experience huge socio-economic losses and paucity of funds upon being hit by a natural catastrophe. This will be the initial move towards building disaster-resilient infrastructure at the national level.

This report, a result of collaboration between the Odisha State Disaster Management Authority and the Coalition for Disaster Resilient Infrastructure (CDRI), focuses on understanding geographical vulnerabilities and the impact of natural hazards on the power sector, particularly across the cyclone-prone state of Odisha.

With two decades of experience in systematically managing natural hazards, Odisha serves as a model for other states in the country to learn in terms of disaster preparedness and risk reduction.

An assessment of the key strategies adopted by the state during Cyclone Fani has presented before us findings that will play a pivotal role in augmenting damage assessment processes and identifying the right approaches to improve the current practices in the power sector (especially during a disaster). An in-depth analysis of geographical vulnerabilities, disaster impacts, quality assurance procedures and overall disaster management strategies is necessary to strengthen the power infrastructure within the state. The next step will be to facilitate informed decision-making, including community-level engagements, to foster a new-age culture of preparedness and resilience for the power sector in Odisha.

This report focuses on documenting exposure mapping, disaster management practices, community and stakeholder survey outcomes, recovery timeline, impact analysis and case studies to help policymakers and relevant administrative bodies advance action-oriented plans for strengthening infrastructure resilience across Odisha's power sector. The report has been divided into three broad sections: a) Preparedness and Survival, b) Recovery and Reconstruction, c) Social and Community Resilience.

Preparedness and Survival are often viewed as the most important aspects of any disaster management plan, but they are often not enough to prevent a disaster. The first section of the report aims to reinforce the importance of preparedness and highlights the role of mitigation in reducing the impact of hazards. The section also assesses the capabilities and processes that the Department of Energy, Government of Odisha, has in place to implement the range of preparatory, preventive and protective actions that may be required for various hazards. Some key learnings from this stage are focussed on stock and equipment review, pre-positioning of people and material, activation of the power control room and preparation of other plans and procedures for the power sector.

Recovery and Reconstruction are long-term processes that involve repairing and replacing damaged equipment and infrastructure. In the context of the power sector, rehabilitation and restoration operations are initiated immediately after a disaster to restore the power system and network to a condition that enable power supply restoration for consumers. Ensuring that the affected areas are not left without power for an extended period is critical for the relief process. The power supply restoration process is a multi-product and multi-stage process that requires a coordinated approach between the power utility, government agencies and the affected community. The second section of the report provides a detailed analysis of the processes and procedures followed by Odisha in the aftermath of a disaster to restore power across affected areas.

Social and Community Resilience of the power system becomes the cornerstone of any disaster management strategy and requires a high degree of coordination between different stakeholders. Odisha's case is a good example of how long-term planning and collaboration can make a difference in enhancing the efficiency of social and community resilience processes during disaster management.

Within each of these sections, a comprehensive list of state-level learnings and recommendations is provided. Some of these recommendations are based on the outcomes of stakeholder and community engagements in the immediate aftermath of Cyclone Fani, which hit the coasts of Odisha in 2019. The good practices adopted by Odisha may help governments at all levels to contextualize their strategies and expected outcomes to minimize risk and increase efficiency for adapting, restoring and recovering from damage caused by natural catastrophes.

The report also includes a detailed discussion of the standard operating procedures (SOPs) that were in place during Cyclone Fani to ensure proper warning dissemination and emergency response. From grid restoration to substation mapping, the report provides a detailed overview of the Odisha power system and the various stages of disaster management that upheld its reliability during the trying times of Cyclone Fani and other similar hazard scenarios.

Overall, this report will serve as a valuable reference to understand the intricacies of disaster management and power system restoration processes and their interdependence. Stakeholders such as the central and state governments, the Ministry of Power and Disaster Management Authorities will find this report valuable in understanding and planning the technological and human resources required for the timely restoration and recovery of power systems in the event of a similar devastating cyclone scenario.

1 Introduction

1. Introduction

Access to reliable and affordable power is the foundation for a modern society. The efficient and continuous operation of a power system is a prerequisite for a country's socio-economic development. Therefore, improving the resilience of power systems is critical for achieving sustainable development goals (SDGs), ensuring economic well-being and improving the quality of life for all.

On 3 May 2019, Cyclone Fani, the strongest cyclone since Phailin in 2013, made landfall near the pilgrimage town of Puri in Odisha, an eastern coastal state in India. Having experienced five cyclones in two decades, the state was well-prepared for systematic disaster management. An early and precise warning about the coming cyclone, combined with strong community mobilization, enabled the state to minimize the loss of lives and human suffering caused by the cyclone.

Based on their experience, Odisha's Department of Energy reviewed contingency plans, pre-positioned funds, materials, workers, equipment and vehicles, and the technical and support staff. It also made communication plans to deal with the cyclone's impact and held advance meetings with critical consumers, including railways, industries, electricity generators and the local load distribution centres, to prevent total grid collapse. Additionally, it planned for the systematic reduction and subsequent restoration of electrical loads during and after the cyclone's passage.[2]

1.1 Impact of Cyclone Fani

Despite the preparations, Cyclone Fani caused over US$ 1.2 billion (estimated) in damages to the power infrastructure in the state. Occasional winds gusting at over 205 kilometres per hour (km/h) disrupted the power supply across 14 of Odisha's 30 districts.[3] High wind speeds uprooted electrical poles, snapped overhead lines, and damaged transformers and other related equipment. As a result, five districts were severely affected, while nine experienced extensive damage, leaving nearly four million people across the state without access to electricity.[4]

Apart from disruptions to economic and industrial activities, the damage to power infrastructure had multiple cascading effects on other infrastructure and public services. Interdependent infrastructure services like transportation, telecom, water supply, medical and healthcare, and banking services were also interrupted by the lack of power,[5] limiting people's access to critical resources required to recoup and recover from the devastation. On the economic front, revenue losses to distribution companies and earnings of bill collectors (outsourced to third parties by DISCOMs) stood at approximately US$ 36.2 million.[6] The complete restoration of power in the state took almost two months.[7]

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[2]Department of Energy, Government of Odisha
[3]United Nations, ADB, World Bank. 2019. The Cyclone Fani - Damage, Loss, and Needs Assessment (DLNA), Odisha State. Details available at https://recovery.preventionweb.net/media/74593/download-start Download=20240927
[4]United Nations, ADB, World Bank. 2019. The Cyclone Fani - Damage, Loss, and Needs Assessment (DLNA), Odisha State. Details available at https://recovery.preventionweb.net/media/74593/download?startDownload=20240927
[5]News reports
[6]United Nations, ADB, World Bank. 2019. The Cyclone Fani - Damage, Loss, and Needs Assessment (DLNA), Odisha State. Details available at https://recovery.preventionweb.net/media/74593/download?startDownload=20240927
[7]Department of Energy, Government of Odisha

Such disruptions have also been shown to have longer-term direct and indirect impacts on the functioning of businesses and the well-being of households.[8] Studies have shown that natural hazards are among the leading causes of power outages worldwide.[9] The cyclone's impact served as a reminder of the need for disaster and climate-resilient power infrastructure systems in Odisha and across the country. This event also highlighted an opportunity for India to build back better and be more resilient. Current estimates suggest that India will need US$ 3 billion annually or US$ 62 billion cumulatively to achieve universal access to electricity by 2030.[10] Therefore, such investments must remain resilient to disaster and climate risk.

In this context, enhancing resilience refers to 'strengthening the ability of a system and its component parts to anticipate, prepare for, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through the preservation, restoration, or improvement of its basic structures and functions' (IPCC 2012). While there are existing international best practices for risk reduction in the power sector, India will have to adopt more robust solutions to its own situation and context.

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[8]Hallegette S., Rentschler J., Rozenberg J. 2019. Lifelines: The Resilient Infrastructure Opportunity. Washington, DC: World Bank Group

[9]World Bank. 2019. Stronger Power: Improving Power Sector Resilience to Natural Hazards. Washington, D.C.: World Bank Group.

[10]Banerjee Sudeshna Ghosh, Barnes Douglas French, Mayer Kristin, Samad Hussain A., Singh Bipulendu Narayan. 2014. Power for All: Electricity Access Challenge in India. Washington, D.C. : World Bank Group

To achieve this goal, the Coalition for Disaster Resilient Infrastructure (CDRI) held consultations with stakeholders involved in developing policies and conducting research at the national level. Particular emphasis was placed on engaging with stakeholders involved in building and operating Odisha's power generation, transmission and distribution infrastructure with Cyclone Fani as the focal point. The consultations highlighted the damages and losses faced by the power sector. They facilitated brainstorming on a road map to build disaster- and climate-resilient power infrastructure in Odisha and, by extension, across all high-risk regions in India. There was a strong consensus on the need for a detailed analysis regarding the cyclone's impact on the state's power infrastructure. This analysis should include the technical, organizational and operational factors contributing to the extensive damages, including the subsequent time required for power restoration.

It was proposed that CDRI initiate an in-depth study to enhance the power sector's resilience to disasters in collaboration with the National Disaster Management Authority (NDMA), the Odisha State Government and other relevant stakeholders. It was also noted that Odisha's power sector has developed and implemented multiple innovative approaches to manage the risk presented by cyclones based on past experiences. Such innovations, adopted continuously over the last two decades, needed to be systematically documented and disseminated to ensure that Odisha's progress benefits other states affected by cyclones.

1.2 About the Study

The study aims to foster resilience for the power infrastructure across Odisha (as well as other Indian states) in the face of natural catastrophes, especially those emanating from extreme climatic events. This will be done by raising awareness and enhancing risk management strategies among stakeholders in the power sector. This, in turn, will strengthen their capacity to take alleviatory steps to help states cope with the impact of future disasters.

The study is being conducted in three parts. Each component focuses on three topics of increasing complexity and scale to augment Odisha's power infrastructure.

1.2.1 Component I

Disaster Preparedness and Management

1. Preparedness and Survival
2. Recovery and Reconstruction
3. Social and Community Resilience

The first component focuses on developing and adopting mechanisms for ensuring preparedness, preventing grid collapse, assessing losses, estimating recovery needs and channelling adequate funds to disaster-affected areas on time. These measures will be essential for early restoration and recovery to improve the power sector's resilience. The component also examines aspects of community engagement to determine the available information and support and their effect on the public's resilience to the impact of the cyclone.

1.2.2 Component II

Risk Mapping and Improvement of Infrastructure

1. Risk Identification and Estimation
2. Codes, Standards, Design, Regulations, Technology and Innovation

The second component involves carrying out a multi-hazard risk assessment of the various components of power infrastructure in Odisha with further appraisals of the prevailing standards, primarily to identify gaps and scope for improvement. The component also focuses on technology selection options that could improve resilience. Component II, thus, provides a technical road map for phase-wise improvement of power infrastructure.

1.2.3 Component III

Institutional Capacity and Financing for Resilience

1. Risk Governance and Policy Development
2. Financing Resilience and Adaptation
3. Capacity Mapping, Development and Knowledge Management

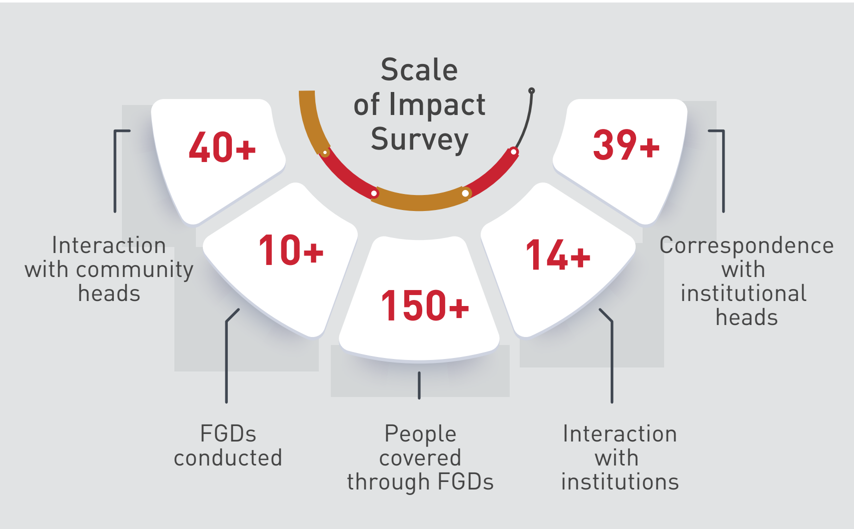
The third component makes recommendations on the enabling environment to support the achievement of the road map defined in Component II. It analyses policies, plans, finance, governance mechanisms, capacity building and knowledge management needed to support the transition. These recommendations will strengthen the state's efforts to achieve disaster and climate resilience for its power infrastructure.

This report is the output of Component I.

Literature review: Developing a methodological approach for the study necessitated an understanding of the power sector's larger problem statement, delving into global and domestic literature in context, identifying potential replicable solutions in consultations with power infrastructure stakeholders and developing implementation scenarios. The literature review focussed on identifying the key drivers of infrastructure resilience along with the perspectives of international communities and agencies towards building disaster-resilient infrastructure, especially in the power sector. The underlying objective of conducting a detailed literature review was to understand the major aspects of disaster management and infrastructure resilience and briefly highlight the power sector's vulnerabilities towards climate disasters.

The literature review was followed by a sample consumer impact survey across the state of Odisha.

1.3 Study Methodology



Impact survey: A consumer impact survey was carried out to verify the key sectoral findings highlighted during the literature review. The survey reached out to various categories of power users, including communities, industries and stakeholders across the power sector, and analyzed the cyclone's impact on power disruption.

Information-gathering methodologies included focus group discussions (FGDs), key informant interviews (KIIs) and questionnaire-based surveys. Surveys were conducted across two priority districts (Puri and Jagatsinghpur) based on the damage and losses incurred after Cyclone Fani hit the state. Target regions were identified based on an impact assessment across multiple categories of customers (Annexure 10). Further, over 100 on-site and telephonic discussion sessions with community representatives were undertaken to arrive at each outcome leading to a significant action point. The survey's results and outcomes were categorized under community, institutional and stakeholder surveys, detailing the on-ground impact, with some prevailing even a year after Cyclone Fani.

A detailed study of Odisha's disaster management process, documenting the daily impact and the state's recovery efforts during Cyclone Fani, helped identify potential gaps in the power sector's disaster response and recovery activities. These gaps were further leveraged as opportunities to identify global best practices that power utilities worldwide have adopted to address similar challenges.

A list of proposed recommendations has been derived based on an analysis of such gaps with further scrutiny for techno-commercial analysis. This stage involved discussion with key vendors to determine an estimated cost impact and implementation timelines for identified recommendations. These recommendations were further consolidated and structured into a business case covering the following aspects:

1. Challenges
2. Current practices
3. Identification of gaps
4. Areas of intervention
5. Expected outcomes
6. Approaches
7. Estimated costs
8. Stakeholder ownership
9. Implementation timelines

Structuring each recommendation across defined timelines supported the design of a road map of actionable solutions for a disaster-resilient power system.

1.4 Structure of the Report

The report structure is based on five key segments, highlighting the activities that were undertaken through the course of the study:

Part I Literature survey: A literature review was conducted on crucial areas related to disaster management, such as identification, mitigation, preparedness, response and recovery.

Part II Community impact assessment: To assess the impact of Cyclone Fani on power users and consumers in Odisha, a survey was conducted in the most affected areas of the state. The survey covered communities, institutions and stakeholders in the power sector. The survey findings highlight the extent of the impact on the community and institutional power users and the key performance aspects of various stakeholders.

Part III Gap assessment: Gaps in the state's current disaster management process have been identified based on benchmarking best practices adopted by global utilities in similar geographies. Such gaps reinforce potential actions that can be undertaken to enhance the robustness of the disaster management process.

Part IV Proposed recommendations and best practices: This section highlights some of the best practices adopted by the state during Cyclone Fani and provides key actionable recommendations. The recommendations are also supported by cost implications that will further help map key developments in the context of disaster resilience and techno-commercial requirements.

Part V Road map and way forward: This segment covers the implementation road map corresponding to the identified interventions. It also covers key aspects such as timeframe, costs and ownership.

1.5 Quality Assurance

To ensure the quality of the deliverables of the study, the CDRI Secretariat instituted the following mechanisms for quality control and verification:

1. The Secretariat formed a Steering Committee comprising relevant national and international stakeholders to review and approve the project deliverables.

2. The Secretariat engaged technical experts with extensive experience within the power sector to provide technical reviews of the deliverables submitted by the consultants.

The project deliverables were regularly presented at consultation meetings with the Government of Odisha and relevant government agencies to ensure the study outputs were useful and aligned with their local development objectives.

The study's outputs in Odisha are expected to be applicable and relevant to regions with similar risk profiles worldwide. CDRI will convene initial dialogues and consultations with member countries in cyclone-affected regions like the Pacific and Caribbean to identify opportunities to apply these learnings. Similar national and sub-national-level studies can also be conducted in these countries to identify context-specific and graded recommendations to strengthen the resilience of the power sector.

CDRI will also work with advanced nations to develop a road map for redeveloping ageing infrastructure in their regions. Overall, CDRI aims to develop a set of context-specific road maps for power infrastructure resilience, considering a range of hazard and socio-economic settings.

2 Odisha Power Sector

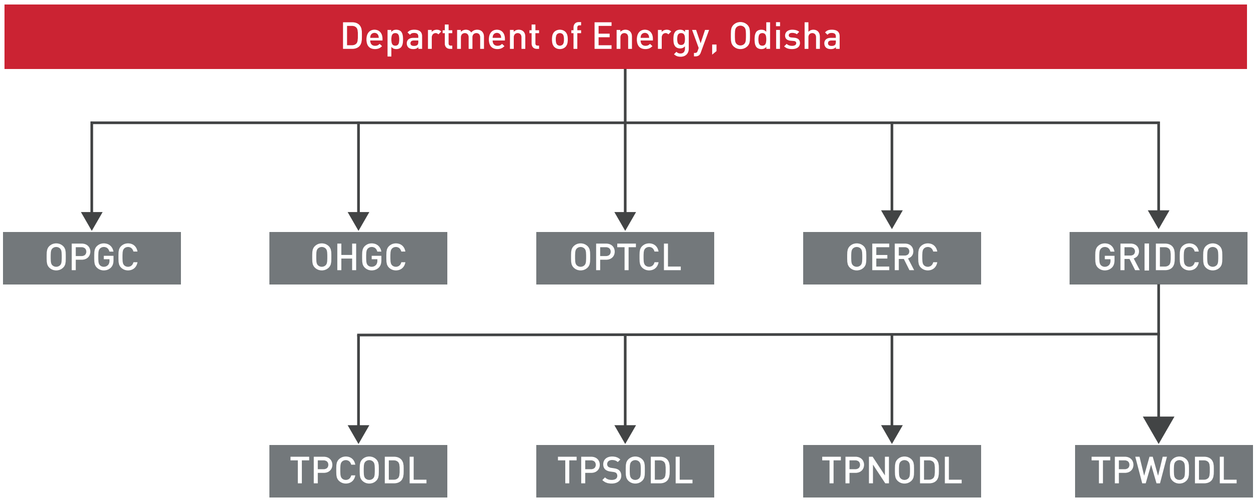
2. Odisha Power Sector

Key Departments, Hazard Exposure and Disaster Management

Odisha, also once known as the Utkala region, is located on India's eastern coast. It shares its border with five other states: West Bengal and Jharkhand to the north, Chhattisgarh to the west, Andhra Pradesh to the south and Telangana to the southwest, along with over 480 kilometres (km) of coastline to the east.

2.1 Energy Department Structure

Figure 2.1: Structure of Department of Energy, Odisha



Odisha's Department of Energy comprises a discrete arrangement of public sector undertakings (PSUs) and private sector entities (see Figure 2.1). The department oversees five independent bodies (specific to the energy sector) that collectively deliver access to reliable power.

Odisha Power Generation Corporation (OPGC) is a publicly owned company with a total generation capacity of 1740 megawatts (MW). It operates thermal power plants in the Jharsuguda region. OPGC's primary objective is to establish, operate and maintain large stations generating thermal power.

The eighth largest state in the country, Odisha has over 42 million citizens and a per capita income of US$ 1,362, thereby securing a national rank of 24 (in terms of GDP per capita).

Odisha Hydro Power Corporation Ltd. (OHPC), a public sector undertaking of the Government of Odisha, has a total installed capacity of 2027.5 MW and operates seven hydropower stations across the state. OHPC's primary objective is to acquire, establish, operate, maintain, renovate and modernize hydroelectric generating stations throughout Odisha.

Odisha Power Transmission Corporation Limited (OPTCL), a public sector undertaking of the Government of Odisha, manages the transmission business and wheeling of electricity in the state, along with the additional responsibility of the State Load Dispatch Centre (SLDC). OPTCL owns over 14,500 circuit km of transmission lines and 163 substations, with a transformer capacity of 22,150 megavolt amperes (MVA) through 366 transformers.

Odisha Electricity Regulatory Commission (OERC) is an independent, autonomous regulatory body that rationalizes the generation, transmission, distribution and supply of electricity across Odisha. Its key functions include setting tariffs, reviewing policies, issuing licenses, reviewing investments and restructuring the state's electricity industry.

Grid Corporation of Odisha Limited (GRIDCO), a public sector undertaking of the Government of Odisha, primarily operates with four private distribution companies (DISCOMs) wholly owned by Tata Power after the privatization of Odisha's distribution unit in 2020. These are Tata Power Northern Odisha Distribution Limited (TPNODL), Tata Power Central Odisha Distribution Limited (TPCODL), Tata Power Southern Odisha Distribution Limited (TPSODL) and Tata Power Western Odisha Distribution Limited (TPWODL).

GRIDCO is engaged in bulk purchasing and selling power to four DISCOMs within the state and trading surplus power to promote power exchange with neighbouring states.

The Government of Odisha also manages the **Odisha Renewable Energy Development Agency (OREDA),** which promotes the adoption and popularization of non-conventional and renewable energy sources across all economic sectors. Table 2.1 lists the Odisha power sector's scale of operations.

Table 2.1: Scale of operations: Odisha Power Sector[11]

Power Generation	
Source	**Capacity (MV)**
Hydro	2085
Thermal	880
ISGS	1217
IPP and Small Hydro	2507
CPP	5628
Renewable Projects	33
Total	8168

Power Transmission	
Source	**Capacity**
EVH Substations	154
EHV Transformers	425
Transmission Lines (ckt kms)	14,241
Total Installed Capacity (MVA)	20,356

[11]State Load Despatch Center. n.d. Generation capacity.
Details available at https://www.sldcorissa.org.in/upload_file/GENERATION _CAPACITY.pdf, last accessed 25 October 2021

Power Distribution	
Source	Capacity (MV)
Sub-Station (33/11kV)	689
Power Transformer (Nos.)	1,497
HT Poles (Nos.)	12,28,545
33/0.4kV Transformer	533
11/0.23kV Transformer	54,880
11/0.4kV Transformer	69,264
33kV Lines (in kms)	10,275
11kV Lines (in kms)	1,22,173
DT Installed Capacity (MVA)	1,67,595
LT Poles (Nos.)	22,20,973
LT Lines (Nos.)	1,54,483

2.2 Geographical Vulnerabilities

Odisha is exposed to multiple geo-climatic conditions, making it vulnerable to high-intensity hazards (see Figure 2.2). In terms of overall disaster resilience, it ranks fourth by measuring disaster-related risks and resilience at a sub-national level across India.[12]

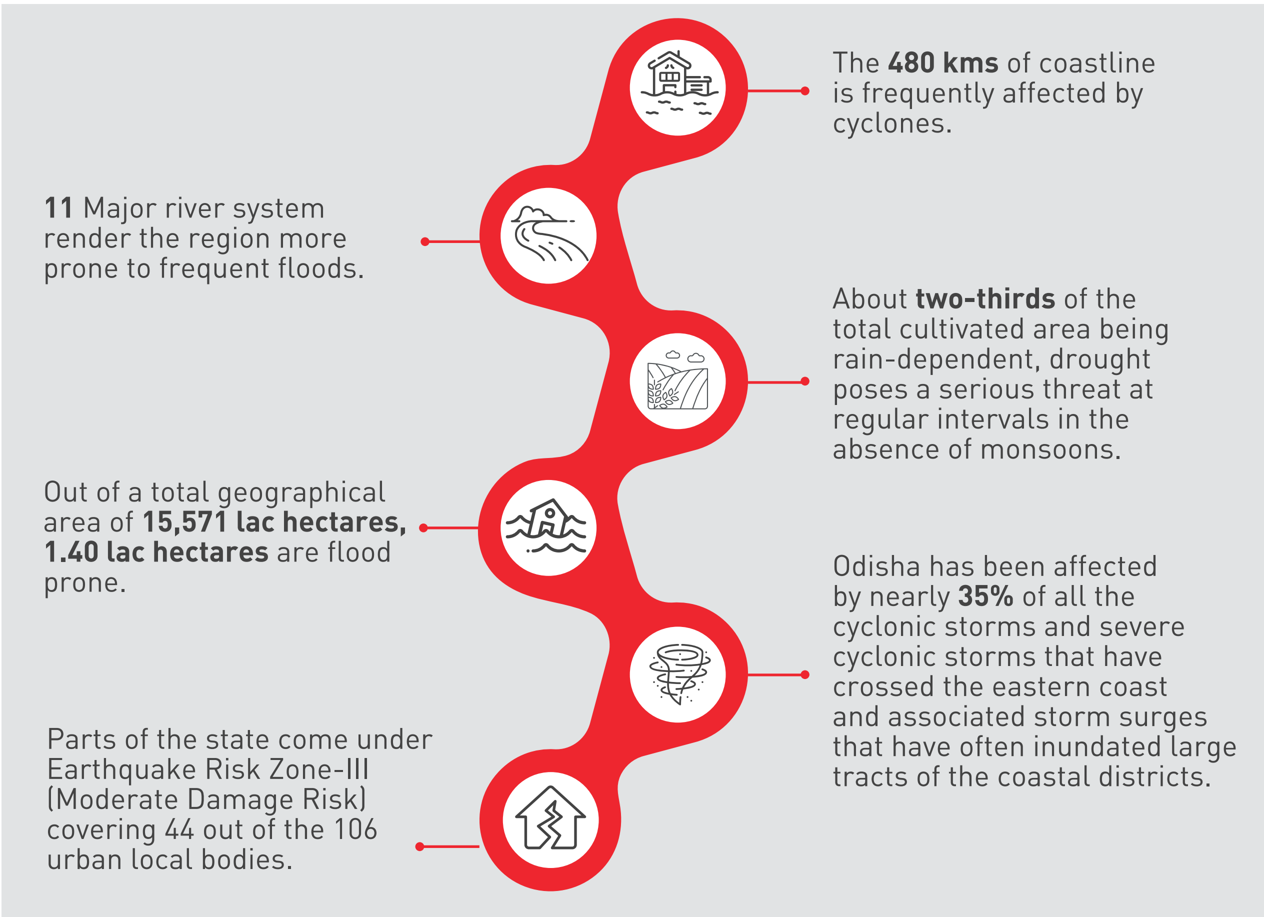
The state tops the list of vulnerable states in India with a score of 90 out of 100 on the Disaster Risk Index, having been exposed to major natural hazards in the past.

Evaluated on a scale of 0-10 against the NDMA's hazard indices, Odisha has secured the following ranks and scores,[13]

- Cyclone Hazard Index: 6.87 (Rank 2)
- Tsunami Hazard Index: 3.49 (Rank 6)
- Flood Vulnerability Index: 2.73 (Rank 9)

Key Geographical Challenges in Odisha

Figure 2.2: Key geographical challenges in Odisha



[12]Details available at https://fincomindia.nic.in/writereaddata/html_en_files/fincom15/Reports/XVFC_202021%20Report_English_Web.pdf, last accessed 25 October 2021
[13]NDMA. 2018. Disaster Score Card for States and Union Territories of India. New Delhi: NDMA. Details available at https://ndmindia.mha.gov.in/NDMINDIA-CMS/viewsituationImportantLetterPdfDocument-103

2.3 Hazard Prioritization for the Power Sector

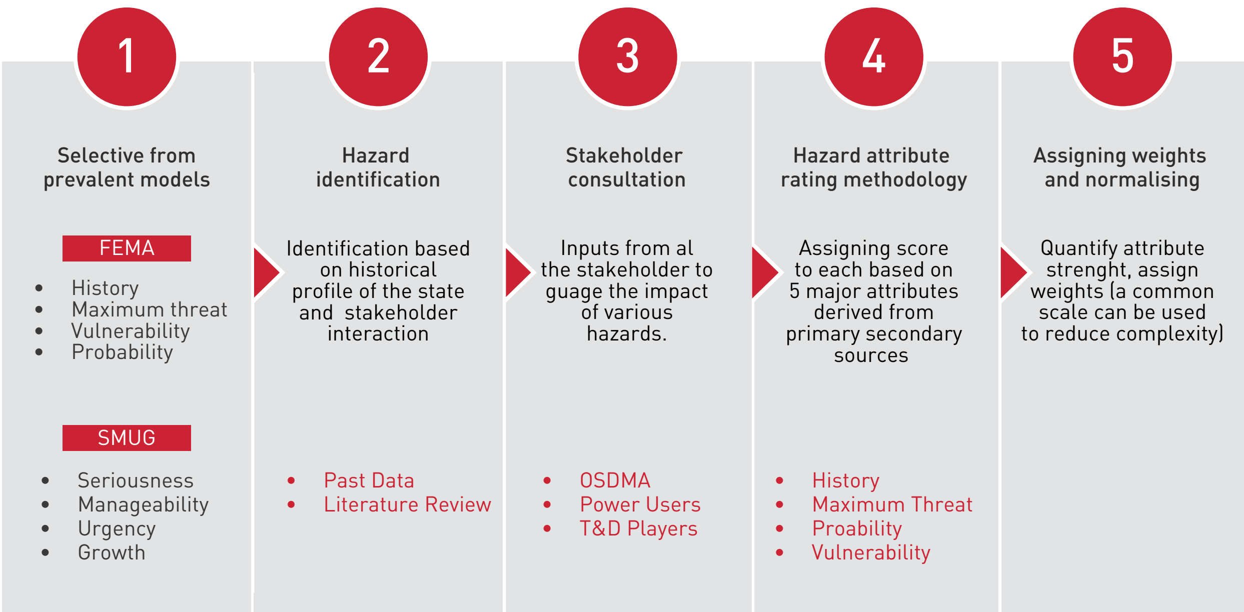
Throughout history, Odisha has been exposed to a plethora of hazards, leaving the state's livelihoods and socio-economic structure in shambles. Depending on the nature and intensity of the damage inflicted by hazards, there is a need to systematically follow an approach that prioritizes and also identifies the array of natural calamities affecting the socio-economic landscape of Odisha. This will enable methodical and evidence-based planning to boost the resilience of critical infrastructure further.

Hazard prioritization is essentially a five-step process (see Figure 2.3):

1. Selecting hazards from prevalent models
2. Hazard identification
3. Stakeholder consultations
4. Hazard attribute rating methodology
5. Assigning weights and normalizing

A methodological approach involving existing models, stakeholder consultations and past impact analysis

Figure 2.3: Hazard prioritization approach



2.3.1 Selecting from prevalent models

Given Odisha's exposure to multiple hazards, it is paramount to amalgamate existing frameworks and models such as the Federal Emergency Management Agency (FEMA) and Seriousness, Manageability, Urgency and Growth (SMUG). Doing so to determine key attributes of various hazards and define them in the state's context would help prioritize prevention.

FEMA was selected for this analysis for the following reasons:

- It was deemed more appropriate with respect to the criteria for each model and their relevance to Odisha's hazards.

- FEMA's model rates each hazard individually using quantitative criteria, whereas SMUG com pares hazards using qualitative criteria. Therefore, FEMA was selected for its data-driven analyses and decision-making qualities.

Constraints in data availability limited the FEMA model's end-to-end replication. However, the model's parameters were used to subjectively evaluate hazard prioritization.

2.3.2 Hazard identification

Critical hazards were identified based on historical occurrences, frequency of disasters, Odisha's hazard profile and stakeholder interactions. Further, Odisha State Disaster Management Authority (OSDMA) conducted studies, including district-wise vulnerability mapping to multiple hazards, to help identify the exposure identification of each district corresponding to the scale of disasters. Further, the hazard profiles were determined by studying reports, literature reviews and stakeholder interactions.

2.3.3 Stakeholder consultations

The Delphi method was adopted for hazard prioritization analyses, with input from a panel of experts.[14] Data inputs were gathered from key stakeholders in Odisha's power sector and disaster management segment. The input parameters included a history of occurrences, damages and impact, and the restoration and recovery parameters needed to achieve business as usual (BAU), loss of life, casualties, etc.

Annexure 11 lists experts consulted for insights and data-gathering on hazard prioritization.
Key stakeholders for the study included the following:

» OSDMA
» OPTCL
» GRIDCO
» DISCOMs
» End consumers and industries

[14]The Delphi method or Delphi technique, also known as Estimate-Talk-Estimate or ETE, is a structured communication/ survey technique,originally

2.3.4 Hazard attribute rating methodology

Although a hazard can be defined by its attributes, it is also crucial to define and rate these attributes based on their impact and risk.

Each of the attributes has values assigned from 1-3 (i.e., 1 – low, 2 – medium and 3 – high) based on some quantitative and subjective analysis. The following key attributes were considered for the hazard prioritization study:

History: This attribute primarily captures the historical occurrences of the specific disaster concerning Odisha. However, the low number of natural catastrophe events from the past does not rule out the possibility of future emergencies.

Maximum threat: This attribute assumes the most serious events and the greatest impact possible, expressed in terms of human casualties and property loss. Secondary events (such as dam failure following an earthquake) are also considered.

Vulnerability: This attribute captures the potential impact on the community and infrastructure specific to disasters through hazard and community maps.

Probability: Determined by the historical frequency and scale of disasters via historical trend analyses, this attribute captures the likelihood of a disaster occurring in the future.

2.3.5 Assigning weights and normalizing

Defining the scale and corresponding score for every hazard's notable attribute is a prerequisite to quantifying its strength. Each attribute is further measured across a common scale to avoid inconsistencies and reduce complexity. In Odisha's case, equal weights have been assumed for all the attributes for a standardized and generalized outcome.

2.3.6 Outcomes of hazard prioritization

Based on the FEMA model, the hazard prioritization study reveals that Odisha is highly vulnerable to cyclones and floods compared to other major disasters.

Frequent events with increasing wind speeds, followed by torrential rainfall, have led to higher relative scores of cyclones and floods than other disasters. It is also worth noting that Odisha has experienced four cyclonic hazard events in three consecutive years (ending in 2021), contributing to the state's increased scores across history, vulnerability and probability parameters.

The scores assigned to the maximum threat of cyclones can be justified by the fact that the total damage and losses caused to the state during Cyclone Fani (2019) are approximately four times the total damage and losses caused to the state during Super Cyclone (1999).

Table 2.2 captures the consolidated result of the hazard prioritization study, showcasing the risks posed by each hazard to Odisha. Further, a detailed exposure analysis for the identified and prioritized hazards would assist in shifting focus towards more vulnerable segments of the power sector.

Table 2.2: Hazard prioritization study: outcomes

Hazard	History		Vulnerabiity		Maximum Threat		Proability		Total score
	Scale	Score	Scale	Score	Scale	Score	Scale	Score	
Cyclone	High	3	High	3	High	3	High	3	3
Flood (Fluvial)	Medium	2	High	3	High	3	High	3	2.75
Drought	High	3	Low	1	Medium	2	High	3	2.25
Heatwave	Medium	2	Low	1	High	3	High	3	2.25
Lightning	Medium	2	Low	1	Medium	2	High	3	2
Tsunami	Low	1	High	3	Low	1	Low	1	1.5
Earthquake	Low	1	Low	1	Low	1	Medium	2	1.25
Coastal Erosion	Low	1	Low	1	Low	1	Medium	2	1.25
Landslide	Low	1	Low	1	Low	1	Low	1	1

2.4 Exposure Mapping of Power Infrastructure

Exposure mapping helps determine the overall risk to the power infrastructure and identifies critical areas for intervention. This involves superimposing the geographical location of infrastructure components on a hazard map to identify exposed assets. Identifying risk-prone locations is imperative to prepare for response and recovery.

For this study, data required for exposure mapping was collated from various sources, including OSDMA. Being the state's nodal agency for disaster management, OSDMA provides district-wise multi-hazard maps on its website. These maps are based on the second edition of the Vulnerability Atlas of India compiled by the Building Materials and Technology Promotion Council (BMTPC) under India's Ministry of Housing and Urban Affairs (MoHUA), capturing hazard data up to 2006. It may be noted that since 2006, only a couple of cyclones have exceeded the maximum wind speed zone of the BMTPC hazard map of 50 metres per second (m/s) or 180 km/h.

Up-to-date hazard data and climate change-related projections are needed to achieve optimal preparedness for disasters, especially climate change-induced events. Currently, such data is unavailable. Phase II of the study will focus on creating an updated risk map, including climate change related projections.

In the absence of updated hazard data, mapping asset exposures to historical hazards will aid the Government of Odisha in identifying regions within the state that have been at disaster-related risk throughout history and require special attention in planning preparedness activities.

While achieving accurate risk estimation with outdated data is difficult, the mapping would suffice to ascertain the regions where hazards could have the maximum impact and where preparedness actions could be prioritized.

For power infrastructure, GIS data is maintained by the transmission and distribution companies separately. While OPTCL has completed the GIS mapping of all its transmission assets in the state, GRIDCO-managed distribution assets have yet to be comprehensively mapped. However, the company has a few distribution-level maps available, mostly compiled for specific projects in the recent past. The current study used the geographical locations of 33/11 kilo Volt (kV) transformers as a proxy for asset locations.

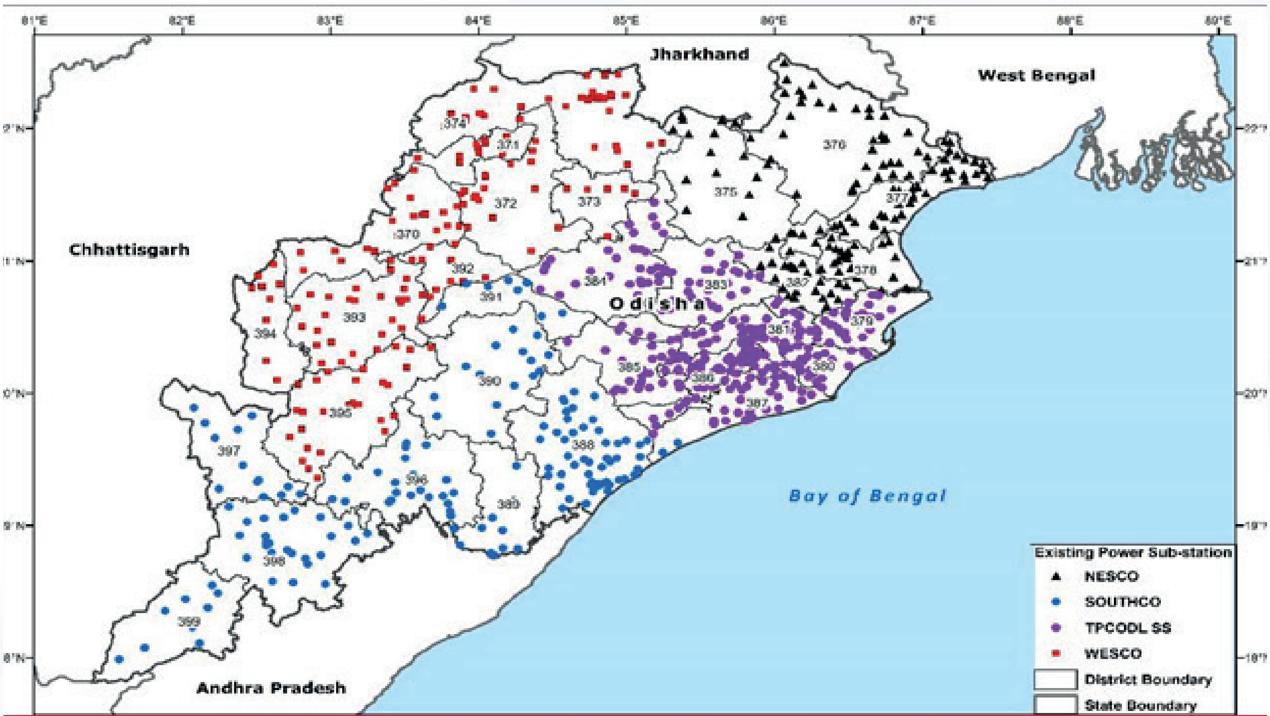
These transformers act as a link between the transmission and distribution assets, serving as a reliable indicator that can indicate the presence of these assets in any region.

The next section presents exposure mapping outcomes for wind, flood and earthquake hazards.

2.4.1 Exposure mapping of 33/11 kV power substations

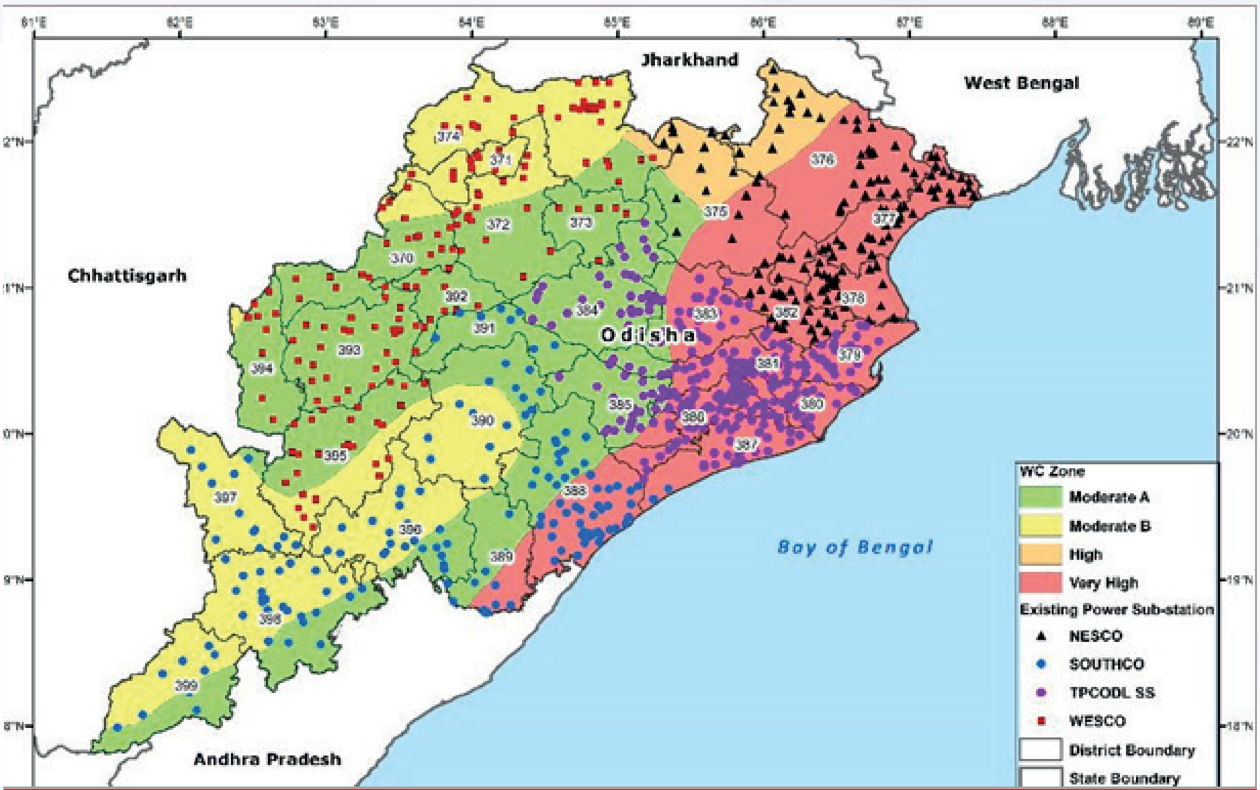
As a first step, the existing power substations of the four power DISCOMs Central Electricity Supply Company of Odisha Ltd. **(CESU) (TPCODL), SOUTHCO (TPSODL)**, WESCO **(TPWODL)** and NESCO **(TPNODL)** were mapped (Figure 2.4).

Figure 2.4: Mapping across four DISCOMs: 33/11 kV transformers



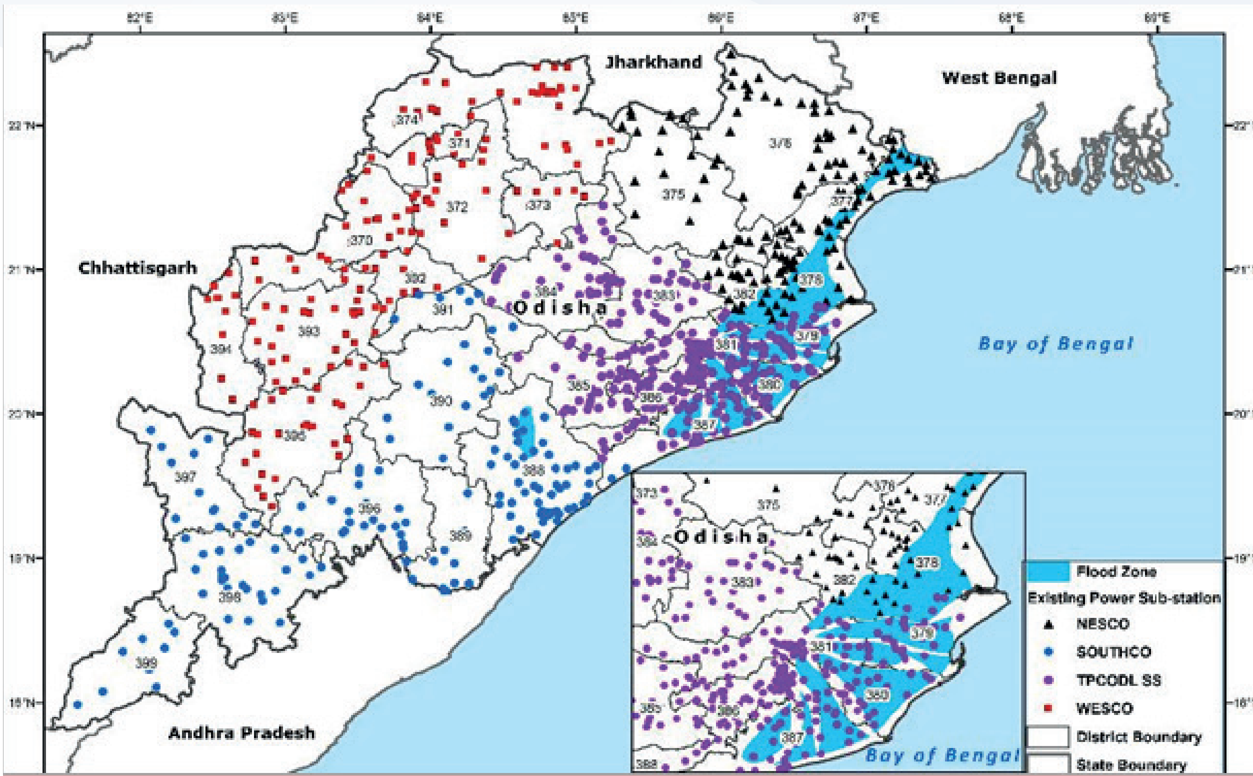
Subsequently, an asset-level map (Figure 2.5) was superimposed over three hazard maps to estimate the risk level attributable to their location and vulnerability in the past.

Figure 2.5: Wind and cyclone (WC) exposure: 33/11 kV transformers



The wind and cyclone exposure map in Figure 2.5 shows that major areas of service under NESCO (TPNODL), CESU (TPCODL) and SOUTHCO (TPSODL) lie in the very high wind and cyclone hazard zone. Vulnerable districts include Puri, Ganjam, Gajapati, Bhadrak, Kendrapara, Baleshwar, Khordha, Mayurbhanj, Jagatsinghpur, Cuttack, Jajpur and Dhenkanal.

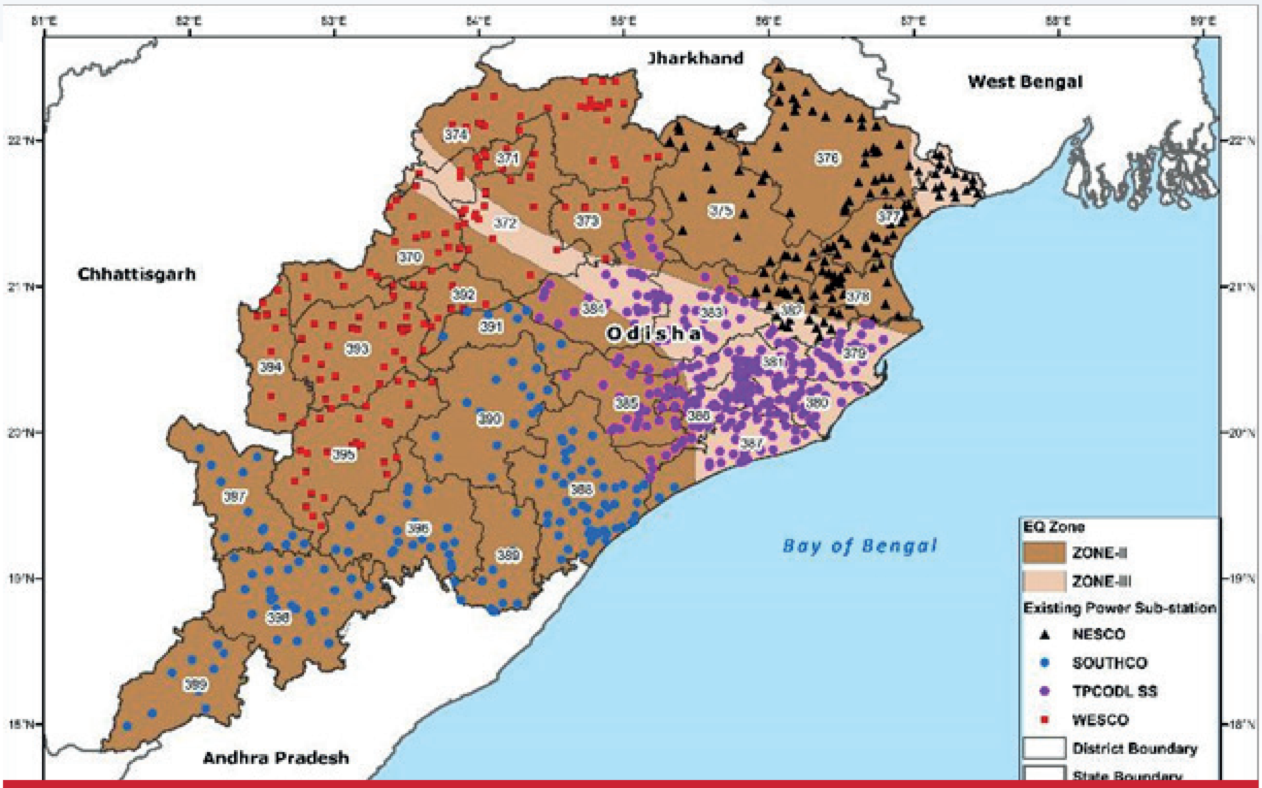
Figure 2.6: Flood exposure: 33/11 kV transformers



The flood zone marked in Figure 2.6 indicates the delta regions of the Mahanadi and Brahmani-Baitarani rivers, which are highly vulnerable to flooding, even with a marginal increase in river flow. The region is also exposed to very high wind hazards, compounding the asset damage risks during the cyclone season.

The coastal districts of Jajpur, Bhadrak, Kendrapara and some parts of Balasore, Puri and Jagatsinghpur are at high risk of flood inundation. The average reported flood depths in these districts range from 0.5 m to 1.5 m. Substations under TPCODL are comparatively more vulnerable to floods. Mapping also shows that 113 of 820 distribution substations are located in flood-prone zones.

Figure 2.7: Earthquake exposure: 33/11 kV sub-stations



Most parts of Odisha lie in Zones II and III of earthquake-prone areas. Zone II is a low-intensity zone with an intensity of 6 (or less) on the M.M. Scale (see Figure 2.7). At the same time, Zone III is a moderate-intensity zone with an intensity of 7 on the M.M. Scale. Of the total 820 distribution sub-stations, 513 and 307 lie in earthquake Zone II and Zone III, respectively. Most TPCODL assets (in purple) in Puri, Kendrapara, Jagatsinghpur, Cuttack, Khordha, Angul and some parts of Sambalpur lie in Zone III.

2.4.2 Outcomes of hazard prioritization and exposure analysis

According to Odisha's power system's hazard prioritization and exposure analysis, tropical cyclones and floods pose the highest risk to the state's power infrastructure. Over 53 percent of total substations (33/11 kV) in Odisha are exposed to high windspeeds (→118 km/h), of which over 60 percent lie in TPCODL's service area (previously CESU). Over 15 percent of the total substations are exposed to inundation due to floods and storm surges, of which over 70 percent lie in the TPCODL's service area (previously CESU).

Of all the four DISCOMs in Odisha, TPWODL (previously WESCO) was the least exposed to hazards. Based on the analysis, it is observed that TPCODL (previously CESU) has the maximum exposure to hazards. Therefore, a capacity enhancement programme, for disaster preparedness and response must be initiated at TPCODL to minimize downtime and impact on communities. See Table 2.3.

Table 2.3: Hazard prioritization and exposure analysis

DISCOM	Vulnerable Districts (Wind → 50m/sec + Earthquakes: Z-III + Flood prone)	Exposed Assets (33/11 kV Sub-stations)
TPCODL (CESU)	**Cyclone:** Puri, Cuttack, Khordha, Kendrapara, Dhenkanal **Earthquake:** Puri, Cuttack, Khordha, Kendrapara, Angul, Dhenkanal **Flood:** Puri, Cuttack, Kendrapara	**Cyclone:** **264** (32%) **Earthquake (Z-III):** **264**(32%) **Flood:** **76** (9%)
TPNODL (NESCO)	**Cyclone:** Mayurbhanj, Jagatsinghpur, Balasore, Bhadrak **Earthquake:** Mayurbhanj, Jagatsinghpur, Balasore, Bhadrak **Flood:** Jagatsinghpur, Balasore, Bhadrak	**Cyclone:** **123** (15%) **Earthquake (Z-III):** **31** (4%) **Flood:** **32** (4%)
TPWODL (WESCO)	**Cyclone:** Sundargarh, Jharsuguda, Bargarh, Sambalpur, Deogarh	**Earthquake (Z-III):12** (1.5%)
TPSODL (SOUTHCO)	**Cyclone:** Ganjam, Jajpur **Earthquake:** Jajpur **Flood:** Ganjam, Jajpur	**Cyclone:** **51** (6.2%) **Earthquake (Z-III):** **Nil** **Flood:** **5** (0.6%)

In the medium to long term, the impact on identified vulnerable assets within the power sector can be mitigated by taking a two-pronged approach: (i) reinforcing the existing infrastructure by adhering to design specifications and improving operation and maintenance of the power infrastructure and (ii) replacing vulnerable/damaged infrastructure with improved standards and technology solutions. These measures will inherently increase the capacity of infrastructure components and networks to withstand the impact of frequent hazards.

Components II and III of CDRI's study will entail a detailed risk assessment to recommend improvements across power component and network standards.

2.5 Disaster Management

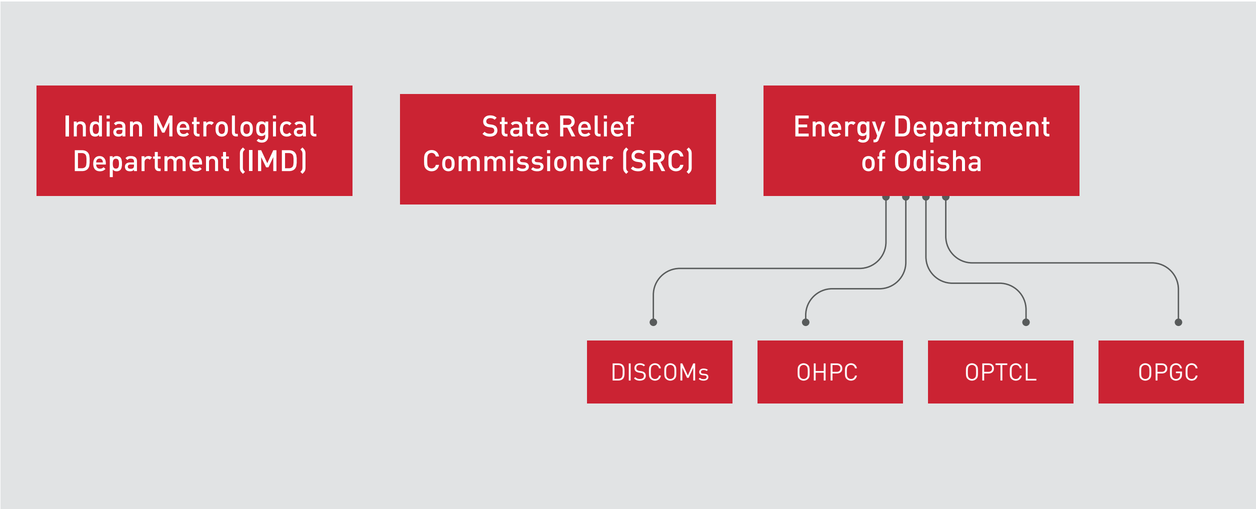
According to Section 40 (1) of the Government of India's Disaster Management Act, 2005, all departments within the state government, in conformity with the guidelines laid down by the state authority, are required to prepare a disaster management (DM) plan. Odisha's power sector stakeholders (Section 2.1) and the Department of Energy devised DM plans (in line with OSDMA's State Disaster Management Plan). While each stakeholder has detailed mechanisms in place for actions to be taken during a disaster, the Department of Energy's DM plan serves as an overarching framework for each stakeholder to prepare, act and respond to disasters. Table 2.4 summarizes the availability of DM plans across different power sector stakeholders.

Table 2.4: Intra-sectoral disaster management plans for stakeholders

Stakeholders of Odisha Power	Availability of Disaster Management Plans
Energy Department of Odisha	Yes
Odisha Power Generation Corporation (OPGC)	
Odisha Hydro Power Corporation (OHPC)	
Odisha Power Transmission Corporation Limited (OPTCL)	Yes
Central Electricity Supply Utility (CESU)	
Southern Electricity Supply Company of Odisha Limited (SOUTHCO)	Yes
Northern Electricity Supply Company of Odisha Limited (NESCO)	Yes
Western Electricity Supply Company of Odisha Limited (WESCO)	

In the event of a cyclone, Figure 2.8 shows the schematic flow of cyclone warnings issued by the Indian Meteorological Department (IMD) to the enabling agencies, i.e., DISCOMs. The IMD centre in Bhubaneshwar, Odisha's capital, issues a notification as soon as it detects the formation of cyclonic storms. The frequency of notifications/warnings issued during the formative stage is every 2 to 3 hours, subsequently increasing to an hour when cyclonic storms are nearing landfall.

Figure 2.8: Information flow of cyclone warnings to Odisha power sector stakeholders



Notifications issued by IMD include the following parameters, which are subject to change during a cyclone:

- Cyclone trajectory
- Cyclone eye diameter
- Probable windspeed
- Probable impact areas
- Storm surge height and rainfall
- Estimated time and areas of landfall

Annexure 1 contains detailed standard operating procedures (SOPs) on cyclone warning dissemination by IMD.

The DM plan encompasses two parallel activities:

(i) Operational flow
(ii) Financial flow

2.5.1 Operational flow

The operational flow typically encompasses the sequence of activities undertaken after the issuance of cyclone advisories by IMD:

1. Warnings disseminated by IMD are acknowledged by the chief managing director (CMD) of the respective stakeholder organization (generation/transmission/distribution).

2. CMD apprises the chief general managers (CGMs) of the impending hazard and its probable implications based on the information delivered through warnings, thereby issuing directions for necessary preparedness actions.

3. The CGMs, comprising primarily operation and maintenance units, inform all concerned field engineers to initiate preparedness actions and consolidate resources (including work force, spares and equipment) as per the disaster management plan.

4. A 24x7 control room is in operation as a supervisory and coordination centre to track, comprehend and direct actions in line with the evolving situation based on upstream and downstream communications. This helps ensure coordinated restoration activities. Stakeholders typically use landlines, mobile phones (SMS, Call, VoIP and internet messaging tools such as WhatsApp) and hotline communication through the SLDC to exchange information.

5. Private rate-contract holding agencies are intimated to mobilize the required workforce (as per agreed terms) across risk-prone regions and vehicles, fuel, food and other resources. Rate contract holders also provide logistics support during the preparedness phase.

6. Related OPTCL grid substations and DISCOMs' division offices function as local control rooms for resource mobilization. Operation and maintenance teams re-check infrastructure components for any probable failure points, thereby undertaking necessary last-minute preventive maintenance operations to enhance the infrastructures' capacity to withstand hazard impact.

7. Buffer stock of components and spares are mobilized from nearby warehouses to offices across high-risk areas.

8. An initial damage assessment is conducted immediately after a disaster, primarily by local workforces on foot and motorbikes, to ascertain damage levels and restoration needs.

9. Based on damage assessments, the required workforce and spare/equipment are mobilized to the adversely impacted sites for timely power restoration.

2.5.2 Financial flow

The following mechanisms are available for Odisha's power sector stakeholders to access funds necessary for undertaking preparedness, response, restoration, recovery and reconstruction activities in the event of a disaster:

- **State disaster relief fund:** Power utilities in Odisha leverage the state disaster relief fund to conduct necessary preparedness and response activities. When they receive warnings about an approaching cyclone, the power utilities allocate funds for critical response and preparedness activities. These funds are used to gather additional resources (workforce, components, etc.), carry out preventive maintenance and procure emergency commodities such as fuel, food and accommodation for workers.

- **Budget allocation for the energy department:** The Department of Energy has earmarked funds from its annual budget towards developing a disaster-resilient power system. Allocated funds are used to procure components and spares to enhance power infrastructure capacity to withstand disasters. Power utilities also leverage the funds allocated for disaster-resilient power systems to procure equipment during restoration phases.

- **Loans from financial institutions, banks and open market:** As per their needs, power utilities borrow funds from financial institutions/banks/open market, with prior approval from the state government, to conduct DM functions. The released funds are used during the restoration and recovery stage to procure resources, settle wages and manage operational expenses.

- **Grants and aid from government and other agencies:** Grants and aid received by the state government are dispensed based on the estimated damage and requirements quoted by respective utilities. Thereafter, funds received by utilities are utilized for restoration and reconstruction to rebuild damaged infrastructure.

2.5.3 Gaps in implementation of DM plan

While a DM plan acts as an overarching framework for response and recovery activities, certain gaps in the process may lead to lapses in implementing these plans. The study captured the following gaps that should be addressed to strengthen DM within the power sector:

1. **Implementation record of good practices or impact areas:** While Odisha has undertaken many steps to mitigate the impact of disasters (especially cyclones), the current DM plan fails to record key impact areas or good practices. By systematically recording key impact areas and best practices from previous disaster events, replicating successful strategies and further reducing response times would be easier.

2. **Documenting key learnings:** The current DM plan lacks structured documentation of the lessons learnt from previous disasters. Creating such documentation would make it easier to transfer knowledge and experiences to new employees and provide a quick reference for making critical decisions.

3 Cyclone Fani

3. Cyclone Fani

Impact and Implications for Odisha's Power Sector

India is at a higher risk of being hit by tropical cyclones due to its proximity to the equator and location surrounded by three major water bodies. The country's eastern coast, in particular, is one of the world's six most cyclone-prone regions, with historical data showing it to be the most vulnerable compared to any other area in India. The data also identifies Odisha as one of the most adversely affected states due to tropical cyclones along the eastern coastline.

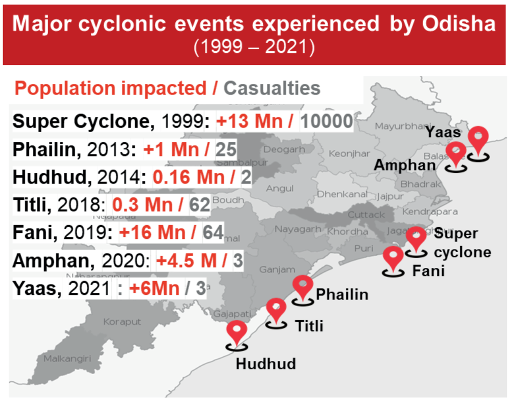
Over the last 100 years, the subcontinent has experienced 1019 cyclonic disturbances, of which over 80[15] impacted Odisha's coastline alone (excluding depressions). Notably, Odisha's coastal belt is significantly more vulnerable. To elaborate, approximately 25 percent of the total climatic disturbances affect Odisha's coastline as compared to other eastern coastal states across India, such as West Bengal (14%), Andhra Pradesh (13%) and Tamil Nadu (7%).

Quick Facts

- Odisha witnessed four cyclones in three years (ending 2021), making them the most frequent and devastating natural hazard for the state.
- Odisha experienced cyclone-related damages worth INR 32,000 crores during the period 2010–20.

Odisha has been affected by 80 cyclonic disturbances in the past, with more than 55 being storms and over 25 being severe cyclonic storms. Seven of these 25 severe cyclonic storms have hit the state over the last 25 years (ending 2021) alone: Super Cyclone (1999), Phailin (2013), Hudhud (2014), Titli (2018), Fani (2019), Amphan (2020) and Yaas (2021) (see Figure 3.1).

Figure 3.1: Major Cyclonic Events: 1999 to 2021



In Table 3.1, various cyclonic events that hit Odisha have been listed. Between 1999 (the incidence of Super Cyclone) and 2021 (the incidence of Yaas), it has been observed that Cyclone Fani caused the most extensive damage and loss in terms of public infrastructure, with the power sector sustaining the major brunt. This can be attributed to factors intrinsic to the power sector, such as the increased quantity and density of power infrastructure assets, limited design improvements, poor maintenance and upkeep, and external factors, such as higher wind speeds vis-à-vis design capacities.

[15]Government of Odisha. 2019. Memorandum. Details available at https://www.srcodisha.nic.in/calamity/Memorandum_Cyclone%20FANI_3rd%20May%202019.pdf, last accessed on 9 January 2022

Table 3.1 Major Cyclones in Odisha

Particular	Super Cyclone	Phailin	Hudhud	Titli	Fani	Amphan	Yaas
Year of impact	1999	2013	2014	2018	**2019**	2020	2021
Peak wind speed (kmph)	260-270	214	80-100	130-140	**205**	120-165	130-140
Districts affected	14	19	11	17	**9**	6	8
Population impacted (Mn)	13+	1+	0.16+	0.3+	**16+**	45+	6+
Total impact (INR Cr)	6,228	4,242	780	2,780	**24,176**	237	610
Power sector impact (INR Cr)	400	1,048	60	133	**8,139**	75	150
% of Total impact	6.4%	24.7%	7.7%	4.8%	**33.7%**	31%	24.6%

3.1 Tropical Cyclone Fani

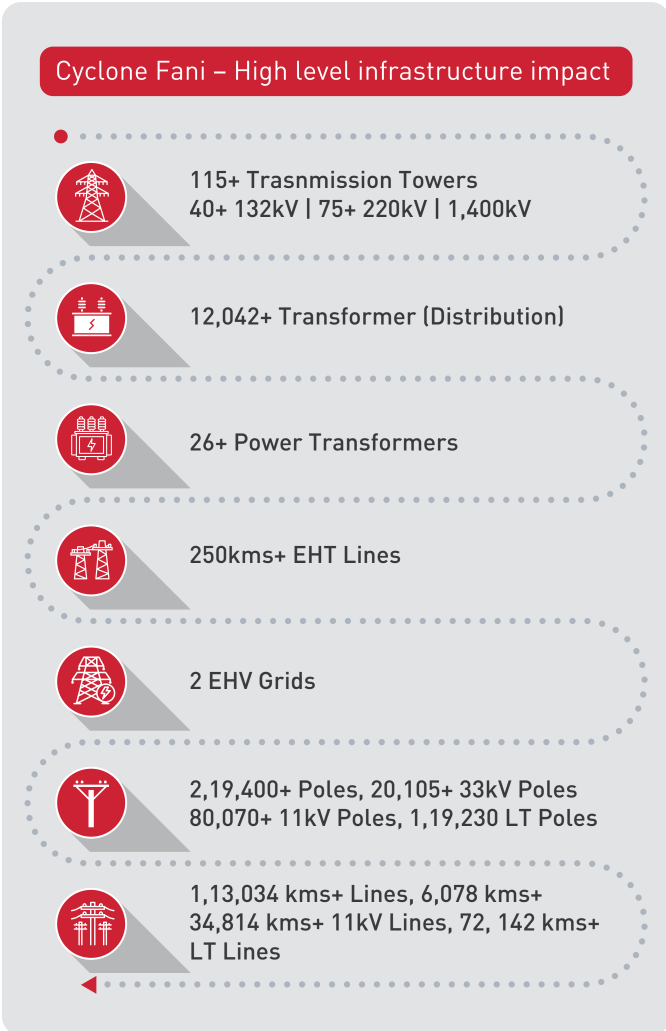
Cyclone Fani emerged on 25 April 2019, beginning as a low-pressure formation. Within 24 hours, it intensified into a cyclonic storm over the Bay of Bengal and Indian Ocean. Near the Puri district, wind speeds recorded during the landfall on 3 May 2019 ranged from 175 km/h to 185 km/h, eventually gusting to 205 km/h. This characterized Cyclone Fani as one of Odisha's 'Extreme Severe Cyclonic' storms. The cyclone affected 16 million people across 14 districts, namely, Angul, Balasore, Bhadrak, Cuttack, Dhenkanal, Ganjam, Jagatsinghpur, Jajpur, Kendrapara, Keonjhar, Khordha, Mayurbhanj, Nayagarh and Puri.

Cyclone Fani's high wind speed and heavy rainfall led to damage and losses worth US$ 3.22 billion.[16] However, with timely and extensive evacuation activities led by the Odisha State Disaster Management Authority (OSDMA), Odisha Disaster Rapid Action Force (ODRAF), and other central and state response agencies, the state minimized the number of lives lost. Nearly 1.5 million people in vulnerable areas (i.e., around the region where Cyclone Fani hit) were evacuated and safely stationed across designated cyclone shelters.

[15]Government of Odisha. 2019. Memorandum.
Details available at
https://www.srcodisha.nic.in/calamity/Memorandum_Cyclone%20FANI_3rd%20May%202019.
pdf, last accessed on 9 January 2022
[16]United Nations, ADB, World Bank. 2019. The Cyclone Fani - Damage, Loss, and Needs Assessment (DLNA), Odisha State. Details available at https://recovery.preventionweb.net/media/74593/download?startDownload=20240927

3.2 Implications for Odisha's Power Sector

Figure 3.2: Cyclone Fani: impact analysis for Odisha power sector Impact of Cyclone Fani on Odisha power 1



Cyclone-induced damages to the power sector can primarily be attributed to high and gusty winds coupled with heavy rainfall. Cyclone Fani led to massive transmission and distribution infrastructure damages due to the exposure of transmission assets to high wind speeds in hazard-prone areas such as coastlines. This also led to over INR 8139 crores of losses for Odisha's power sector value chain. The impact encompassed damage to infrastructure and financial losses stemming from operational disruptions, particularly in the power sector. Moreover, power infrastructure components such as transmission towers, distribution poles, transformers, power lines and substations were severely impacted, and adverse consequences followed for retail and institutional power consumers.

Given the three-fold increase in the state's power demand (Table 3.2) since 2000, it has become critical to assess hazards and develop a road map for building resilient infrastructure across the state's geographies, especially across its coastal pockets.

3.3 Recovery Timeline

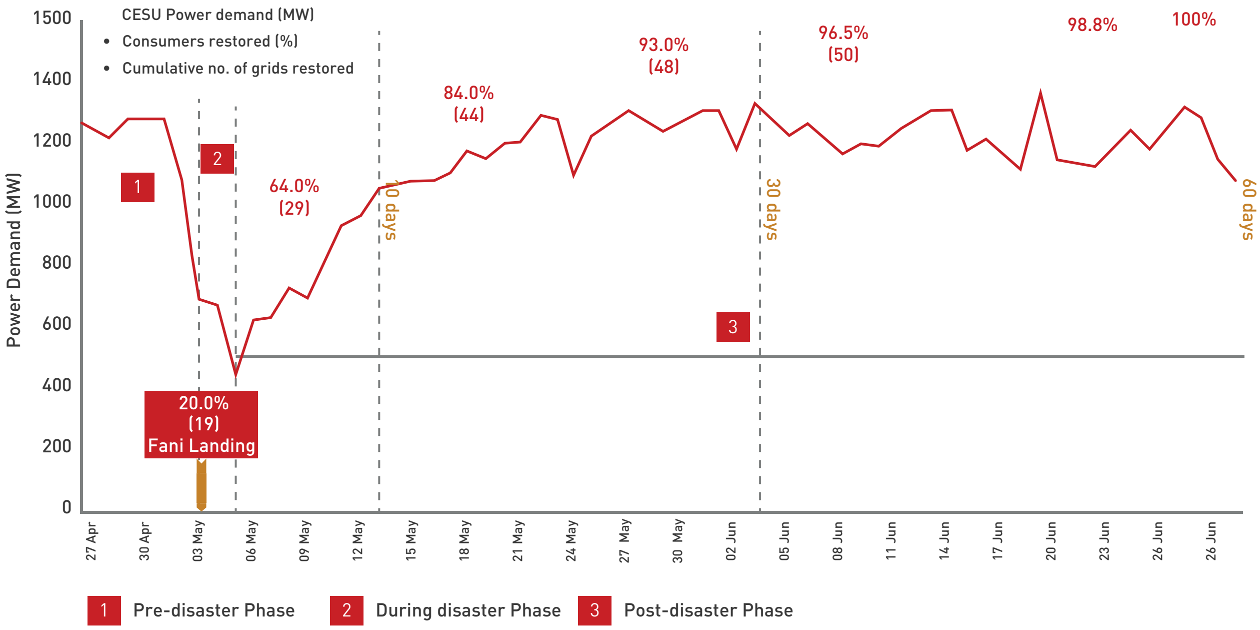
After Cyclone Fani struck on 26 April 2019, IMD's central and state offices shared regular notifications until its landfall in Puri on 3 May 2019, around 08:00 hours. More importantly, there was a significant drop in power demand (up to 70%) (Figure 3.3), with Tata Power Central Odisha Distribution Limited (TPCODL) (previously Central Electricity Supply Company of Odisha Ltd or CESU) being among the most impacted elements.

Table 3.2: Growth in system demand

Peak power demand (MW)	1679 MW (FY 2000)	4200 MW (FY 2019)
Household electrification	43% (FY 2011)	100% (FY 2019)
Per capita electricty consumption	874 kwh (FY 2010)	1672 kwh (FY 2017)

IMPACT ON POWER DEMAND DURING CYCLONE AND RESTORATION

Figure 3.3: Impact on power demand during cyclone and restoration



Demand variation across the system gives further perspective regarding the impact of Cyclone Fani across various timelines, restoring system load and a sequence of actions undertaken throughout the cyclone's timeline. This report segregates pertinent timelines into three phases: Pre-Cyclone Fani, During-Cyclone Fani and Post-Cyclone Fani to assess the activities carried out by the state's power department.

[16]United Nations, ADB, World Bank. 2019. The Cyclone Fani - Damage, Loss, and Needs Assessment (DLNA), Odisha State.
Details available at https://recovery.preventionweb.net/media/74593/download?startDownload=20240927

The pre-Cyclone Fani phase covers actions taken to minimize the impact of the cyclone on the power sector. The primary aim of this stage was to ensure that power systems and processes were strengthened through preventive maintenance, stockpiling and strategic positioning of resources. The power demand in the system was at 1246 MW (as of 27 April 2019) and 1273 MW (as of 1 May 2019), indicating the system's sustained power demand. During Cyclone Fani, multiple activities were undertaken to minimize its impact, including pre-positioning of people and materials at strategic places, setting up control rooms, holding meetings in advance with critical customers to mitigate the potential impact of power disruptions, advanced procurement of consumables and devising rate contracts with vendors for immediate access to components and spares. To deal with post-facto scenarios as per their evolution, disaster response centres (DRCs) were also set up to monitor the response activities centrally.

Key Activities Undertaken during the Pre-Fani Phase

- Activation of control rooms; defining roles and responsibilities
- Interactions with power users in vulnerable areas
- Ration procurement for restoration workforce
- Finalizing rate contracts with key vendors
- Authorized and decentralized purchase of low-value components
- Pre-positioning of people and materials at strategic places

The during-Cyclone Fani phase broadly captured all the pre-defined critical activities the Department of Energy undertook following the cyclone's landfall. These were essentially aimed at minimizing damage and bracing for impact from high wind speeds, water surges and others that could cause abrupt power demand drops. The power demand dropped by 58 percent over 24 hours, from 1070 MW (2 May 2019) to 453 MW (5 May 2019). This happened potentially due to outages across Cyclone Fani-affected areas, owing to a preventive shutdown of certain sections across the power grid. Further, the Department of Energy commenced resource mobilization based on a first-hand assessment of the impact on power infrastructure feeding critical installations.

Key Activities Undertaken During Cyclone Fani

- Preventive electrical feeder shutdowns in high windspeed areas
- Gathering real-time information on infrastructure damage from field level control rooms
- Continuous monitoring and assessment of power supply scenario for critical establishments

The Post-Cyclone Fani phase captures all the immediate, mid- and long-term restoration activities undertaken to 'build-back-better.' Owing to the extensive damage and loss caused to Odisha's power sector, restoring power to normalcy took over 60 days. The primary aim of the phase was to replace or repair damaged assets as soon as possible, with minimal spillover effects for consumers. Some key impact activities undertaken during this phase included community engagement, mobilization of materials and workforce, and emergency restoration towers' deployment to enable parallel restoration. As illustrated in Figure 3.3, the system took over 30 days to restore 84 percent of the power demand, with 100 percent of it being met within 60 days of the cyclone's landfall.Restarting power lines (initially shut under preventive shut-downs), diversions via alternative circuits and working on quick restorable sections of the power network were some of the key immediate steps undertaken by CESU for power system restoration. Critical institutions such as hospitals, government offices and other essential establishments were immediately restored, helping the system regain some levels of demand following the weakening of Cyclone Fani. The key to a resilient power system is its ability to achieve desired operational capacity levels in the wake of disruptions.

The remaining 16 percent of the system's demand was restored via major infrastructural works, which required extensive electrical material and workforce transportation across difficult-to-access areas (primarily clogged by uprooted trees, waterlogging, flooding, etc).

Key Activities Undertaken in Post-Cyclone Fani Phase

- Immediate damage assessment by foot/vehicle
- Mobilization of reserve materials and workforce from ongoing sites, nearby states and utilities
- Community personnel assistance for power restoration
- Increase in labour rates (up to 1.5 times)

3.4 Community, Institutions and Stakeholders

Cyclone Fani significantly impacted 14 state districts that covered 159 blocks, comprising 18,388 villages and was home to 52 towns. Cuttack, Dhenkanal, Ganjam, Khordha and Puri were among the districts that bore the brunt of the cyclone's force. The impact on the power infrastructure had a cascading effect on the other sectors, with telecom, transportation and public services, including water, health and sanitation, facing disruptions for a prolonged period. In short, Cyclone Fani had varying degrees of direct and indirect impact on the community, institutions and stakeholders.

Multiple rounds of primary and secondary research were conducted with various community power users, institutions across industries and health, sanitation and water establishments. Additionally, consultations were held with stakeholders such as the state's Department of Energy, disaster management (DM) groups, relief agencies, and other state and central departments to assess the overall impact. The selection of each stakeholder herein was vital, taking into account their diverse roles (refer to Table 3.3) in promoting policies and practices that are resilient friendly for Odisha's power sector.

Table 3.3: Role-based stakeholder selection for impact surveys

Stakeholders	Role of Stakeholders
Power Infrastructure Owners (State-level)	
State Power DISCOMs (CESU, NESCO, WESCO and SouthCo)	Regulate and manage power supply and related services to end-users
Odisha Power Transmission Corporation Limited (OPTCL)	Oversee intra-state power transmission to DISCOMs
State Load Dispatch Centre (SLDC)	Real-time grid control management and electricity dispatch within the state
Grid Corporation of Odisha (GRIDCO)	Bulk power procurement and dissipation
Other State and National Entities and Regulators	
Central Electricity Authority (CEA)	Formulate power sector development plans
Odisha Electricity Regulatory Commission (OERC)	Ensure timely cost and operational approvals
Disaster Management Agencies	
Odisha State Disaster Management Authority (OSDMA)	Monitor and coordinate prevention and mitigation strategies against disasters in the state
National Disaster Management Authority (NDMA)	Define policies, plans and guidelines for disaster management to ensure timely and effective response
State Disaster Response Force (SDRF)	Response to disasters and emergencies, along with capacity-building and awareness generation
Odisha State Government Departments	
State Finance Department	Acquire and manage funds to ensure timely deployment of development plans
Revenue and Disaster Management Department (R&DM)	Provide immediate relief to adversely affected people (due to disasters) and take the initiative for relief, rescue, rehabilitation and restoration

Stakeholders	Role of Stakeholders
Department of Industries	Promote all-round industrial development of the state and aid in economic development
Department of Energy	Monitor, coordinate and manage energy sector stakeholders and undertake development plans
Community and Institutional Power Users	
Domestic urban and rural power users	End-users for the domestic low tension (LT) power system
Small and medium commercial establishments	Provide aid to boost local employment and economic development
Small- and large-scale industries	Dependent on power supply for operational continuity; foster local employment and economic development
Critical institutional power users such as hospitals and banks, among others	Provide critical/emergency services dependent on the power supply

Multiple impact surveys, focus group discussions (FGDs) and key informant interviews (KIIs) were conducted to better understand the cyclone's impact on power users. The data collected was analyzed and interpreted to produce actionable insights (refer to Annexure 12 – Sample Survey Questionnaire). KIIs were conducted with community heads from the most impacted villages in rural areas and blocks in urban areas, followed by FGDs with people in these jurisdictions. The key objective of these surveys was to assess the impact of cyclones across all categories of power users and stakeholders and derive insight-driven outcomes. Further, it is vital to take an inclusive approach to assessing the impact of hazards on all power users and stakeholders to gain deeper insights from the survey. The survey, therefore, covered community and institutional power users, power infrastructure stakeholders and other relevant entities. The details of the demographic selection and methodology for the sample survey can be found in Annexures 3 to 8.

Key Highlights of Impact Assessment

- 300+ questions prepared for KIIs and discussions across all users
- 40+ KIIs conducted with community heads
- 10+ FGDs covering 150+ people
- 30+ KIIs with institutional heads
- 20+ sectoral stakeholders interviewed

3.4.1 Community impact survey: approach and outcomes

A preliminary study was conducted across all 14 districts affected by Cyclone Fani to identify the most affected areas (or localities) that had sustained maximum damage. This study was driven by two factors: (i) district vulnerability to hazards and (ii) Fani's overall impact on the state's power infrastructure.

A primary survey was carried out to collect responses (Annexure 10) from power users across Odisha's Puri and Jagatsinghpur districts, which were identified as the worst-affected regions. Out of 30 villages across both districts, wind speeds of over 170 km/h were observed in 20 villages, 120 km/h in 9 villages and 80-90 km/h in one village. See Table 3.4.

Table 3.4: Community impact survey: outcomes

Attributes	Quantifying Impact on Community Power Users
Employment and Livelihood	• **72 percent** of the affected people reported a monthly income loss of up to 70 percent.
	• **45 percent** of the affected people reported reductions in employment days.
	• As per village heads' responses, roughly **1.7 percent** of the population had varying physical disabilities and were increasingly vulnerable to fallen debris, power lines and poles, among others, in the villages.
	• The impact on employment resulted in an estimated loss of INR **1800 crores** (US$ 0.24 billion) of income to people across the state.
Power Supply	• All respondents reported power blackouts for at least **15 days**, causing severe hardship.
	• Only **three village** heads acknowledged the presence of solar panels, but these could not be used as distribution lines were damaged.
	• Roughly **70 percent** of the respondents in the affected regions reported delays in power restoration due to difficulty in accessing damaged power infrastructures
	• Roughly **15 percent** of respondents suffered damages to appliances due to frequent fluctuations following immediate power restoration activities. .

Attributes	Quantifying Impact on Community Power Users
Power Supply	• Most respondents reported poor restoration work, with 11 kV HV lines hanging at approximately **5-6 feet**.
	• Roughly **70 percent** of the respondents indicated their reliance on kerosene, diesel and solar lights for lighting their homes.
	• Roughly **60 percent** of respondents reported that local people got involved in power restoration due to inadequate deployment/availability of workforce from the Department of Energy.
	• Approximately **35 percent** of the respondents expressed their desire to have an underground cabling system in fear of future cyclones.
	• Roughly **93 to 100 percent** of the village/block representatives reported damage to distribution transformers and poles, respectively, causing power supply issues.
	• Roughly **35 percent** of the village/block representatives reported that there were no clear updates on supply restoration by the Department of Energy, which further limited their capacity to disseminate information to local inhabitants.
	• Most respondents reported that they had to remove broken electric poles and wires following the cyclone.
Telecommunication	• **44 percent** of the population in the affected region reported the loss of telecom services due to the unavailability of power.
	• Almost **50** telecom towers were completely uprooted due to high wind speeds in the affected region.
	• Disrupted telecom networks limited villagers' access to critical support and relief services.

Attributes	Quantifying Impact on Community Power Users
Public Services	• **30 percent** of the population reported that the hospitals/ clinics in their region were non-operational for more than two days due to the lack of power.
	• **45 percent** of the schools in the affected region were closed for over a week due to disruptions in the power supply.
	• Most of the population was unaware of the DM plan for the village.
	• Roughly **67 percent** of village heads reported damage to streetlights.

3.4.2 Institutional impact survey: Approach and outcomes

The damage assessment reports published in the wake of the cyclone indicated a widespread but varying impact on institutions, both direct and consequential. Direct impact included damage to physical movable and immovable assets, while consequential resulted from operational disruptions exacerbated by power outages.

Quantitatively, the net impact of the cyclone has been a prolonged subject of debate, as various government departments and institutional groups produced varying numbers based on their assessment methodologies.

Nonetheless, tourism, housing, health, industries, water, rural development and railways, among others, sustained significant damage. Small businesses, specifically self-employed informal workers, experienced income losses ranging from a few weeks to several months. For instance, the tourism sector reported losses worth INR 732 crores in Odisha's State Assembly.

A total of 30 public and private institutions across local mid-level rural, mid-level urban and central/state-level segments were identified for impact assessment. These included hospitals, restaurants, industries, commercial shops, banks and government departments such as fire, police and administration. See Table 3.5.

Institutional Segregation for Impact Assessment

- Local mid-level/rural institutions at village level
- Mid-level urban commercial and industrial institutions, including Bhubaneshwar
- Central/state-level institutions

Table 3.5 Institutional impact survey: outcomes

Attributes	Quantifying Impact on Institutional Power Users
Exposure to Disasters	• **90 percent** of the institutions have witnessed three or more disasters (cyclones) over the last five years.
	• **100 percent** of the respondents acknowledged that their region was the most impacted by the cyclone.
	• Damage to infrastructure and disruptions across critical services such as power and transportation affected the output and unavailability of workforces to resume business.
	• Inadequate response by response teams of dependent services led to longer recovery times.
Damages to Infrastructure	• **60 percent** of institutions in the affected region had suffered damage to their infrastructure.
	• **72 percent** of affected institutions suffered medium or high (severe) damage to their infrastructure.
	• Total damage suffered by institutions in the affected region is estimated to be **INR 20 crores**.
	• Damage caused to infrastructure subsequently accounted for asset loss, which affected business continuity.
Operational Impact	• **60 percent** of the institutions in the affected region were not operational for two days or more.
	• A prolonged period of non-operational days resulted in revenue loss due to reduced/limited operations.
	• Business owners had to opt for deferred cash flows due to reduced cash in hand.
Power Disruptions	• **All institutions (except one)** reported power outage post-cyclone for a minimum duration of 10 days and a maximum of 23 days.

Attributes	Quantifying Impact on Institutional Power Users
Power Disruptions	• **All respondents (except one)** stated that either no steps had been taken by the Department of Energy or were unaware of any measures taken to improve the power infrastructure prior to the cyclone.
	• Commercial and tourism-related power users reported a power outage ranging from **5 to 15** days, hospitals reported **3 to 7 days**, and administration and government departments reported **5 to 23 days.**
	• Almost **97 percent** of institutions witnessed fluctuations and unreliable supply of power post-power restoration.
	• Roughly **50 percent** of institutions stated that responses from power providers were unacceptable.
	• Unreliable or fluctuating power led to losses for customers; **30 percent** of institutions reported damage to their appliances due to fluctuating electricity.
	• Between **43 and 50 percent** of the institutions reported moderate to severe damage to electricity poles/wires/feeders/distribution transformers from which they received power supply.
	• Almost **75 percent** of the affected institutions had no prior information about possible power cuts across identified feeders/power lines during the cyclone.
	• Roughly **72 percent** of the affected institutions denied any significant power infrastructure improvement work undertaken by the Department of Energy following the cyclone in their vicinity.
	• Roughly **67 percent** of the institutions in the affected region had no DM plan, hence, preparedness and response levels to the cyclone were inadequate.
Recovery	• Almost **30 percent** of institutions in the affected region took more than a month to attain revenue levels before the cyclone.

Attributes	Quantifying Impact on Community Power Users
Recovery	• Commercial, industrial and tourism institutions took **30-60** days to regain business normalcy.
	• Key factors behind delayed recovery included the following: • Relatively long time to restore critical services such as power and transportation. • Delayed relief services and support activities, which led to relatively slower recovery at the level of individual workers. • Extensive damages to infrastructure resulting in longer restoration periods.

3.4.3 Stakeholder impact survey: approach and outcomes

Stakeholders such as power infrastructure owners, DM entities, and other state and central institutions were surveyed to assess the cyclone's impact on their businesses and the key activities they undertook pre-, during- and post-Fani.

Stakeholder Segregation for Impact Assessment

- Power infrastructure owners and regulators
- Central level power sector planning and designing
- State disaster management entities

Accordingly, stakeholders were identified based on their roles and responsibilities for ensuring resilient power infrastructure. The scope of the study applied to multiple stakeholders across the power sector value chain, DM officials and policymakers, including the following:

- Four DISCOMs and one transmission company
- OSDMA
- Central Electricity Authority (CEA)
- Odisha Electricity Regulatory Commission (OERC)
- State Finance and Disaster Management Department

Table 3.6 Stakeholder impact survey: outcomes

Attributes	Quantifying Impact, Assessing Preparedness and Steps Taken by Stakeholders
General Perspective of Power Infrastructure Owner	• As per the DISCOMs and the transmission company, cyclones have the most severe impact on physical power infrastructure.
	• CESU faced challenges in power restoration due to the absence of predefined SoPs and framework and contracts for post-Fani restoration work, as most of the contractors were ill-equipped with adequate tools, tackle, hydras, boom vans and more.
Impact on Power Infrastructure	• The failure of joints resulted in underground cable failures at several locations. RMUs, compact S/S, along with FRTU outer body parts were seriously damaged during the cyclone.
	• CESU suffered damages of over **INR 200 crores** (US$ 27 million) due to the cyclone, affecting over **2200 ckt** km of low-tension (LT) lines and **3400 DTs**.
	• OPTCL suffered damages of over **INR 59 crores** (US$ 8 million) due to the damage caused to assets, affecting over **23 km of 220 kV** and **14 km of 132 kV** network.
	• Up to **15 days** were taken to restore transmission networks and over **60 days** to restore distribution networks.
	• Communication systems (including SCADA) failed due to the unavailability of power.
	• Plain cement, concrete, rusted joist poles without concrete/cooping, poor stay wire arrangements and trees collapsing over power lines were among the key reasons for damages to the network of power distribution lines.
Revenue Loss	• CESU in Puri suffered losses of over **INR 12 crores** (US$ 1.6 million) due to reduced billing (up to 40 MU).

Attributes	Quantifying Impact, Assessing Preparedness and Steps Taken by Stakeholders
Revenue Loss	• Power utilities also suffered due to deferred revenues for previous sales, limiting the availability of funds to conduct restoration and other activities.
Other Related Impacts	• The failure of power and telecom networks created cordination issues for restoration and damage assessment teams.
	• A workforce of over **3300** was deployed across Puri during restoration, including **1500** labourers (sourced), 800 departmental staff and **1000** contractor personnel.
	• Public resistance due to inadequate support, blocked roads and transportation of materials were some of the key challenges in the wake of the cyclone.
	• Approximately **50,000** consumer complaints received during the cyclone's impact period could be closed only after 30–35 days across the CESU DISCOM region.
Regulatory Policies and Other Key Practices	• Odisha's state electricity regulations do not mandate the creation of a DM plan for DISCOMs and the transmission company.
	• There was no or inadequate provisioning of funds towards restoration and recovery of power infrastructure by the DISCOMs in their annual revenue requirements.
	• None of the distribution companies factored in the need to enhance the resilience of power infrastructure into their capital expenditure plans.

3.4.4 Key takeaways from the user impact study

- Numerous communities and institutions witnessed losses of all kinds in the aftermath of Cyclone Fani. Given Odisha's heightened vulnerability to hazards, it is vital to understand the efficacy of DM plans that were operational during Cyclone Fani. Although the state's power sector was one of the most severely impacted segments, its cascading impact on other sectors exacerbated the misery and suffering for all.

- Disruptions in critical services such as power, telecom, water and relief services amplified the scale of the impact on communities.

- Impact on consumers can broadly be classified under three categories:

  » **Asset loss:** Damage to infrastructure and machinery caused by high wind speeds and related storm surges, including uprooted telecom towers and electric poles and damage to machinery and infrastructure of industries.

  » **Revenue loss:** Erratic cashflows due to operational disruptions hampered socio-economic activities, and reduced demand and economic activity (due to widespread damage across sectors) also limited the state's revenue inflow.

  » **Income loss:** Reduced demand, disrupted operations, fewer employment days and increased expenses reduced the economy's cash in hand.

- The power sector was most severely affected, with cumulative losses of over 17 percent of the total impact on the state.

- Communities lost an estimated US$ 240 million, facing power outages for over 15 days.

- Industries witnessed over US$ 2.7 million in overall infrastructure damage, with power losses between 15 and 23 days.

- Recurring power outages led to disruption of essential services for all.

- Due to a lack of communication, consumers did not have much clarity regarding power resto ration from Odisha's Department of Energy. As a result, this led to greater suffering for these citizens, thereby limiting their ability to plan for the immediate future.

- Limited pre-disaster readiness initiatives before the disaster's occurrence led to widespread economic losses in terms of asset damage.

- Due to limited resources (skilled workforces and equipment), restoration activities for the power sector were running under capacity, leading to prolonged periods of no power supply.

- The delayed restoration mechanism could also be attributed to manual interventions and a lack of coordination within teams, primarily due to a lack of well-established communication services.

"We have achieved zero loss of life; now, the objective is to enhance resilience and ensure zero loss of power infrastructure during disasters. This can be done through "empowerment", "inclusion", "knowledge sharing" and "joint strategic action plans" among the nations in the Asia Pacific region'."

Sh. Bishnupada Sethi
Principal Secretary, Revenue & Disaster Management

4

Learnings and Recommendations

4. Learnings and Recommendations

This chapter assesses the key actions adopted during Cyclone Fani and identifies corresponding areas for improvement. Some of the best practices adopted by Odisha's power sector during the disaster, along with the proposed recommendations across the stages of response, restoration and recovery, have been categorized thematically. This is primarily for ease of referencing and global adoption. The findings in the chapter can be classified under two heads:

1. **Learnings from Odisha power sector:** The actions and processes adopted by Odisha to respond, restore and recover in the face of Cyclone Fani have been highlighted as best practices that the international community can further adapt and contextualize.

2. **Proposed recommendations:** This consists of comprehensive suggestions that could result in an improvement of current practices in Odisha's power sector as well as the development of potential best practices that can be adopted based on a global best practices study and benchmarking.

The objective of analysing the practices within the disaster management (DM) process is to create a stronger foundation with respect to the following:

1. Identification of potential impact areas.
2. Mobilization of resources during a disaster (i.e., fostering resourcefulness).
3. Enhancement in the pace of restoration to minimize the damage to consumers.

4.1 Preparedness and Survival

The preparedness phase assesses the capabilities and mechanisms that Odisha's Department of Energy has in place to implement a range of preparatory, preventive and protective actions that may be necessary for numerous hazards. This phase mainly involves short-term actions that should be undertaken immediately, before and after a disaster occurs. These actions focus on damage assessment and mobilization of resources to minimize the adverse impact on power users caused by sudden power outages.

4.1.1 Learnings from Odisha power sector

1. **Stock and equipment review:** As soon as IMD issued warnings, stock checks were conducted throughout vulnerable areas. The available quantities of spares and equipment were assessed at warehouses situated across identified areas and nearby locations. This helped in estimating the need for additional supplies and devising a procurement and mobilization strategy for additional requirements.

2. **Pre-positioning and reallocation of resources:** Rate contract holders were informed to mobilize and position skilled workforces, spares and equipment in vulnerable areas so they can be immediately deployed in the aftermath of disasters. A skilled workforce from ongoing projects was also mobilized, which reduced the response time and potential delays caused by disruptions in transportation services. More than 800 workers were moved from ongoing projects, while a workforce of over 6000 was engaged in response and restoration activities.

3. **Activation of a power control room:** Control rooms were set up at SLDC and at the respective DISCOM circle offices to establish a communication mechanism between the IMD, stakeholders and on-ground resources. The primary objective was to share information provided by the IMD promptly and to plan necessary actions through discussions held within corporate offices. Key stakeholders comprised individuals from several teams, including the restoration workforce, damage assessment teams, stock review teams, warning dissemination teams and supervisory staff.

4. **Advance meetings with critical consumers:** To prepare for a potential power supply failure and disruptions across other interdependent services, key consumers, including the railways, Regional Load Dispatch Centre, National Load Dispatch Centre (NLDC) and industries, held meetings and discussions. This communication allowed the company to plan for the continuity of its services in the event of a power disruption.

5. **Procurement guidelines and rate charts:** Rate charts were prepared with empanelled vendors to ensure continuity in the supply of spares and resources during restoration and to minimize the lead time for delivery and recovery.

6. **Advance procurement of consumables:** Bulk purchases of consumables such as diesel for backup power, potable water and food for the restoration workforce, among others, were made to mitigate potential shortages in the aftermath of the cyclone.

7. **Decentralized purchases for less critical parts:** Regional teams were given the authority to procure spares/resources from non-empanelled vendors for less critical (low impact low risk) parts. This was done to minimize the restoration completion time. This policy was put into effect when approved vendors were unable to meet the requirements within the necessary time frame.

8. **Disaster response centres:** Specialized machinery was set up to restore damaged poles, towers and lines. Disaster recovery centres (DRCs) were equipped with cranes, ladder-mounted lights, diesel generator sets and emergency restoration towers (ERS) towers.

4.1.2 Proposed recommendations

Table 4.1 Proposed recommendations in response actions: summary

Intervention Areas	Proposed Recommendations
Technology Integration	• Drone-assisted damage assessment • Leveraging outage management system for failure identification • Adoption of satellite phones for improved communication • GIS mapping of networks • IT-enabled dashboards for real-time inventory visibility
Capability and Capacity Development	• Joint mock drills • Detailed SOP formulation • Digital knowledge management portal
Resource Mobilization	• Resource mobilization via helicopters • Strategic stock positioning-spares bank
New Financing Constructs	• Leveraging liquidity funds through an annual allocation of revenue
Organizational and Operational Adaptations	• Policy adaptation • Improved governance structures Odisha Electricity Regulatory Commission (OERC) integration

1. Drone-Assisted Damage Assessment

Current Practice	Damage assessment post-Fani was undertaken through foot/vehicle surveys. This restricted the workforce's easy movement due to damaged roads and uprooted trees.
Challenges Faced	Restricted movement of the workforce due to damaged, obstructed, or inundated roads further delayed damage assessment and subsequent response activities.
Areas of Intervention	Technology-assisted rapid damage assessment using drone-assisted hybrid arrangements can reduce time and cost.
Global Best Practices	San Diego Gas and Electric[17] deploys drones for multiple purposes to ensure quick and reliable operations during disasters and emergencies. Drones are primarily leveraged to improve inspections and assessment of electric and gas lines in the pre- and post-disaster phase, particularly in remote areas.

Expected Outcomes

- Improved decision-making by identifying some of the worst-affected zones
- Reduced dependence on the workforce for manual assessment

Approach

- Identification of high wind speeds, rainfall and flood zones
- Drone procurement and deployment
- Workforce training on usage and trouble shooting
- Flightpath planning and acquaintance with aerial network expanse

Implementation Timeline

- Up to 06 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 20–22 crores/US$ 2.9 million** (5 Drones per 45 Division offices in nine vulnerable districts – Phase I)

[17]SDGE. 2019. Drone Investigation, Assessment and Repair (DIAR) Program.
Details available at
https://www.sdge.com/sites/default/files/SDGE%20Drone%20Program%20Fact%20Sheet_0.pdf.

2. Leveraging Outage Management System for Failure Identification

Current Practice	Post-Fani, damaged sites were manually identified through workforce movement for post-disaster damage assessment.
Challenges Faced	Manual assessment of damaged sites and failure areas took up crucial time.
Areas of Intervention	IT and automation technologies have limited involvement in addressing disruptions. An outage management system can be leveraged to identify bottlenecks quickly.
Global Best Practices	Potomac Electric Power Company (PEPCO)[18] deployed an outage management system coupled with advanced metering infrastructure (AMI) for more than 2.8 lakh customers in 2011, with a total outlay of approximately US$ 71 million. The system led to annual savings in operation and maintenance costs of over US$ 2.2 million in 2012 and reduced outages and customer complaints.

Expected Outcomes

- Reduced outage durations by fasterrestoration
- Increased visibility on outages and network conditions
- Improved customer satisfaction due to reduced downtime

Approach

- Prioritize customers for phase-wise deployment
- Install smart meters and communication modules
- System integration of modules in outage management tools
- Manage customer availability data and workforce mobilization

Implementation Timeline

- Up to 36 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 8715 crores/US$ 1.1billion** (LTCT smart metre deployment with AMI for nine million customers in Odisha)

[18]PEPCO. n.d. Enhanced Outage and Restoration Information Tools Available for Pepco Customers. Details available at https://www.pepco.com/News/Pages/EnhancedOutageandRestorationInformationTools Available for PepcoCustomers.aspx.

3. Adoption of Satellite Phones for Improved Communication

Current Practice	Post-Fani, damaged sites were manually identified through workforce movement for post-disaster damage assessment.
Challenges Faced	Manual assessment of damaged sites and failure areas took up crucial time.
Areas of Intervention	There is a lack of effective means of communication within and across utilities. Satellite communication can be leveraged to exchange information and ensure coordination within teams. Adopting satellite phones would require a detailed feasibility assessment and regulatory approval, considering the overall scenario to avoid any breach of national security protocols.
Global Best Practices	Brazil's regional power utility, Furnas, acquired mobile communication units that used satellite communication to cater to the communication needs during reconstruction at remote sites; quicker information exchange enabled faster reconstruction.

Expected Outcomes

- Reduced communication lag between workforce teams
- Increased coordination between the energy department, utilities and on-field restoration teams

Approach

- Permission for large-scale usage of satellite phones if any
- Workforce training on the usage of SATCOM phones

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 6.5 crores/US$ 0.9 million** (IsatPhone 2: **INR 1.3 Lakhs** Inmarsat based; for 500 restoration workforce teams, one phone per team)

4. Resources Mobilization via Helicopters

Current Practice	Post-Fani, road transportation was used, which effectively limited the pace of mobilization, given the number of damaged and blocked roads due to uprooted trees.
Challenges Faced	Road transportation resulted in a delay in the deployment of resources to affected areas.
Areas of Intervention	Helicopters can be used for quicker mobilization of resources, including workforce, equipment and spares.
Global Best Practices	Duke Energy[19] deployed helicopters to transport new transmission poles, which allowed the company to transport 320 new steel poles faster and reach areas inaccessible by conventional transportation modes due to blocked roads (attributable to fallen trees and debris).

[19]Wells Jessica. 2019. Helicopters replace massive transmission lines toppled by Hurricane Michael. Details available at https://illumination.duke-energy.com/articles/helicopters-replace-massive-transmission-lines-toppled-by-hurricane-michael, last accessed on 9 January 2022.

Expected Outcomes

- Reduced time in the mobilization of workforce and spares, especially in remote areas
- Reduced dependence on the National Disaster Response Force for route clearance

Approach

- Agreement with charter operators to lease out helicopters during disasters
- Formal intimation to the operator by the utility about the requirement of resources
- Route planning and deployment sequence (area prioritization) to be finalized

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 1.5 crores/US$ 0.2 million** (@ INR 65,000 per hour; 7 days, 3 hours, 10 units – 1 unit per affected district)

5. Joint Mock Drills

Current Practice	Periodic mock drills are being conducted post-Fani, but these are limited to damaged sites and division offices. The workforce is well-versed in the practices, systems and geographies of their respective locations.
Challenges Faced	The workforce has limited work experience and exposure across varied geographies, systems and industrial best practices.
Areas of Intervention	Joint mock drills of the workforce with nearby states are needed based on off-site emergency plans drafted by the Ministry of Power/Department of Energy.
Global Best Practices	The detailed off-site emergency plan, drafted by India's Ministry of Environment, Forest and Climate Change (MoEFCC) focuses on roles, responsibilities and collaborations across agencies and enforcement and implementation of the plan.

Expected Outcomes

- Adaptation of workforces to different terrains and systems
- Increased communication of workforces across utilities
- Driver for mutual aid agreement programme

Approach

- Agreement within utilities for joint mock drills
- Empanelment of training agency
- Nomination of workforce batches (of 200) for quarterly drills
- Drills to be conducted in different participating regions on rotation

Implementation Timeline

- Quarterly frequency

Stakeholder Ownership

- Department of Energy

Estimated Cost

- **INR 40 lakhs/US$ 0.05 million** (Trainer fees + logistics – Per drill)

6. Liquidity Funds

Current Practice	Disaster financing in Odisha comprises government-provided grants and (national/state) disaster relief funds. However, funds allocated for the power sector are insufficient due to the absence of sector-specific funds.
Challenges Faced	Limited experience and exposure to working in varied geographies, systems and industrial best practices.
Areas of Intervention	Revenue allocation on an annual basis can create liquidity funds, which will address the paucity of funds needed to initiate necessary response actions.
Global Best Practices	In the aftermath of Hurricane Michael, Gulf Power leveraged its disaster fund to pay for emergency expenses, including thousands of out-of-state linemen and extra equipment needed to rebuild Bay County's electrical system. Money for the fund was allocated from portions of customers' electricity bills.

Expected Outcomes

- Off-the-shelf availability of funds to carry emergency services
- Increased liquidity during response actions
- Reserve funds for advance procurement of goods and services

Approach

- Creation of utility-owner disaster fund
- Allocation of at least 1.5 percent annual revenue (MoP recommended)
- Pre-disaster cash disbursement for response actions

Implementation Timeline

- Up to 3 months

Stakeholder Ownership

- Utility (Finance)

Estimated Cost

- Not applicable

7. Formulation of Detailed Standard Operating Procedures (SOPs)

Current Practice	The DM plan of Odisha's power sector sequentially outlines the required actions. However, the SOPs of the actions have not been detailed, thereby limiting the purpose of the DM plan.
Challenges Faced	The absence of a well-documented list of sequential actions and stakeholder ownership during a disaster has resulted in delayed response actions.
Areas of Intervention	It is necessary to formulate detailed SOPs for all the key activities to enable a process-driven DM system that ensures pre-defined cost, quality and time targets.
Global Best Practices	Rajasthan Rajya Vidyut Prasaran Nigam Limited,[20] the power transmission wing of Rajasthan's power department, has developed SOPs comprising key actions to be taken during a disaster. Other key features of the SOPs include hazard mapping, communication mechanism, preparedness and response mechanism.

Expected Outcomes

- Established mechanisms for preparing for disaster
- Integration of state specifications in the construction manual
- Documented approach for reconstruction to build back better

Approach

- Assessment of the current SOPs structure and documentation
- Agreement on the new SOP structure
- Gap analysis and recommendations based on gaps identified
- SOP finalization with key stakeholders and dissemination

Implementation Timeline

- Up to 06 months

Stakeholder Ownership

- Department of Energy

Estimated Cost

- **INR 40 lakhs/US$ 0.05 million** (Consulting project for the formulation of SOPs)

[20]Rajasthan Rajya Vidyut Prasaran Nigam Limited. 2019. SOP for Disaster Management. Details available at https://energy.rajasthan.gov.in/content/dam/raj/energy/corporate-one-lines-viewer/pdf/ordercirculars/FROrder/OtherRules/SOPDisaster.pdf.

8. GIS Mapping of Networks

Current Practice	Odisha's power infrastructure is not geographically coded in the current system.
Challenges Faced	Manual intervention in operation and maintenance practices and preparedness actions leads to increased time consumption and reduced accuracy compared to automation and technology-led infrastructure management.
Areas of Intervention	GIS mapping of critical assets will be essential for tracking the health of networks and components throughout a disaster's lifecycle.
Global Best Practices	Avista Utilities[21] geocoded the entire network of the downstream hardware for component-specific vulnerability assessment and damage estimation. The benefits observed after the windstorm in the United States (2021) were as follows: • Reduction in the number of adversely affected customers by 82 percent • Reduction in restoration time by 70 percent

Expected Outcomes

» Component-specific exposure and vulnerability analysis
» GIS-based mobile vegetation management
» Network maps for expedited restoration

Approach

» Differential global positioning systems (DGPS) mapping of the network across utilities
» Integration of a digitalized network in the utility asset management tool
» Integration of digital vegetation management tool into the asset management system
» Vulnerability assessment of assets with respect to hazard exposure

Implementation Timeline

» Up to 24 months

Stakeholder Ownership

» Utility (Operations)

Estimated Cost

» **INR 200 crores/US$ 27 million** (State-wide mapping of DGPS)

[21] ArcNews. 2019. Avista Utility's location-based damage assessment kick-starts a digital transformation. Details available at https://www.esri.com/about/newsroom/arcnews/utilitys-location-based-damage-assessment-kick-starts-a-digital-transformation/, last accessed on 9 January 2022

9. Digital Knowledge Management Portal

Current Practice	Knowledge and experience gained within the current system are limited to the leadership and employees participating in DM processes.
Challenges Faced	Experiences and learnings from historical disaster mitigation practices are not documented. Consequently, the new generation of the workforce does not have direct access to learning and practices.
Areas of Intervention	An integrated digital knowledge management portal can be developed to store documents on internal best practices related to DM over the years.
Global Best Practices	Assam's State Disaster Management Authority[22] has developed a digital knowledge management portal. This portal contains case studies, impact evaluations, training modules, conferences, seminars, workshop documentation, journals, guidelines, disaster management-based books, thought pieces, good practices and reports on events. The knowledge management portal is a webpage that can be accessed by all stakeholders.

Expected Outcomes

- Enables easy knowledge and experience sharing from power sector experts
- Acts as a self-paced learning platform with courses from experts and veterans
- Offers classified sections for templates, presentations, reports and training materials

Approach

- Deployment of a portal for internal communication and reach
- Creation of niche categories for uploading relevant content
- Structuring of modules in the form of training sessions for easy understanding, acceptance and knowledge transfer

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Department of Energy

Estimated Cost

- **INR 80 lakhs/US$ 0.1 million** (Technology consulting, tool deployment and content curation training)

[22]Government of Assam. n.d. Knowledge management portal on DM. Details available at https://asdma.assam.gov.in/portlets/knowledge-management-portal-on-dm, last accessed on 9 January 2022

10. Policy Adaptation

Current Practice	Odisha's current power system policies have not optimally integrated resilience into the framework necessary for improving every disaster's infrastructure capacity, resulting in constant failure. Regulatory inclusions would ensure the adoption of best practices for developing disaster-resilient infrastructure in the state.
Challenges Faced	The state power sector faces repetitive component failure during disasters due to insufficient focus on building disaster-resilient power infrastructure.
Areas of Intervention	Adapting existing policies to enable resilience in the power sector is essential.
Global Best Practices	The Philippines' Department of Energy implemented RCP[23] (Resiliency Compliance Plan) for ensuring resilient energy infrastructure, which includes: • Strengthening existing infrastructure • Integrating structural adaptations into the design of energy infrastructure • Improving operation and maintenance standards for expeditious restoration • Baselining resiliency standards for future construction of energy infrastructure

Expected Outcomes

- » Policies at the central level consist of provisions to include additional costs incurred for disaster resilience in tariffs
- » Policies at the state level, including coastal areas (<60 km), consist of a mechanism that strengthens the overall infrastructure and creates reserve funds through annual revenue allocation (1.5%) at the utility level

Approach

- » Due diligence of existing policies, standards and processes
- » Benchmarking of policies across global utilities
- » Interaction with multiple domestic and international regulators
- » Incremental updates in existing policies for resilience

[23]Senate of the Philippines Legislative Library. n.d. Resiliency compliance plan.
Details available at
https://issuances-library.senate.gov.ph/subject/resiliency-compliance-plan, last accessed on 9 January 2022

Implementation Timeline	Estimated Cost
» Up to 6 months	» INR 2 crores/US$ 0.3 million (Consulting project)

Stakeholder Ownership

» Department of Energy

11. Improved Governance Structure

Current Practice	Regulators are limited in their involvement in strengthening disaster-resilient power infrastructure and systems. However, regulatory bodies can mandate project developers to include disaster resilience in upcoming projects with their approval.
Challenges Faced	In the absence of a governing authority, monitoring the implementation of disaster resilience on the ground becomes difficult. Consequently, this can hinder the sector's overall performance during a disaster.
Areas of Intervention	A governance structure can be set up to acknowledge/oversee investments and projects, with OERC acting as a governing body.
Global Best Practices	In the Philippines, the Energy Investment Coordinating Council (EICC)[24] was set up to streamline regulatory procedures affecting energy projects under a Resiliency Compliance Plan.

Expected Outcomes

- Shorter project approval timelines
- Enhanced governance and project monitoring

Approach

- Mapping of existing (AS-IS) system of monitoring
- Analysing bottlenecks in project approval processes
- Identification of key officials for quicker approvals Analysing bottle necks in project approval processes
- Periodic project monitoring to ensure timely completion

[24]Details available at https://boi.gov.ph/sdm_tags/executive-order-no-30-creating-the-energy-investment-cordinating-council-in-order-to-streamline-the-regulatory-procedures-affecting-energy-projects/

Implementation Timeline	Estimated Cost
» Up to 3 months	» INR 40 lakhs/US$ 0.05 million (Consulting project)
Stakeholder Ownership	
» Electricity Regulatory Authority	

12. Spares Banks

Current Practice	Spares are located at DISCOM-specific warehouses with a limited inventory of critical components (such as transformers). DISCOMs can choose to limit the inventory due to higher costs, which, in turn, affects the restoration process during a disaster.
Challenges Faced	Insufficient critical components during the restoration phase stretch the restoration and recovery process beyond the expected timeline. Prolonged scarcity of spares and resources during restoration occurs due to inadequate inventory planning or inefficient logistics (primarily due to delays).
Areas of Intervention	Pre-disaster preparation will require stock re-positioning of spares and inventories at strategic areas in collaboration with nearby states/utilities.
Global Best Practices	More than 30 utilities in the US and Canada set up a company Grid Assurance[25] for cost-effective inventory pooling. Key highlights: • Secure domestic warehousing of inventory across strategic locations • Planned transportation and logistics support for delivery restoration time by 70 percent during the windstorm in the United States (2021)

[25]Details available at
https://gridassurance.com/grid-resilience-solution/subscriber-benefits/

Expected Outcomes

- Reduced cost by stock-pooling
- Reduced supply chain disruption of spares and inventories
- Reduced adverse impact on restoration due to lack of spares
- Economies of scale

Approach

- Identification of geostrategic areas for the stores-near the borders
- Location-based analysis of warehouse service areas
- Identification of components and quantities based on historical data
- IT-enabled inventory data for increased visibility

Implementation Timeline

- Up to 06 months

Stakeholder Ownership

- Utility (Operations) Authority

Estimated Cost

- Not applicable

13. IT-Enabled Dashboard

Current Practice	Site-specific inventory and resource details are recorded in enterprise resource planning (ERP) modules and extracted based on detailed search and examination.
Challenges Faced	Limited resource visibility due to the lack of a single, consolidated dashboard leads to considerable time spent on inventory management during a disaster.
Areas of Intervention	An IT-enabled dashboard/portal for a consolidated view of resource availability across the state can reduce the time needed to identify necessary resources and make decisions during a crisis.
Global Best Practices	SPAREConnect[26] provides a platform for utility asset owners and operators to communicate with other participants regarding transmission and distribution equipment sharing. Over 120+ utilities across the US and Canada are part of the SPAREConnect programme.

[26]Details available at https://www.eei.org/issuesandpolicy/transmission/Pages/sparetransformers.aspx.

Expected Outcomes

- Increased visibility to inventory and spares availability
- Quicker decision-making towards mobilization
- Enabled replenishment in the case of shortfalls

Approach

- Data consolidation using various data repository systems
- Making use of data visualization tools like Tableau and Power BI
- Exploring SDRN (State Disaster Resource Network)
- Periodic updates regarding inventory (resource-availability) at the substation level

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Department of Energy

Estimated Cost

- **INR 60 lakhs/US$ 0.08 million** (Technology consulting, tool deployment and system integration)

4.2 Rehabilitation and Restoration

Rehabilitation and restoration operations are integral to DM processes. They refer to actions taken in the aftermath of a disaster to establish an uninterrupted or relatively stable power supply. This ensures access to basic services through temporary fitments that would have minimal impact on consumers' lives.

4.2.1 Learnings from Odisha power sector

Some key learnings from Odisha's power sector, with respect to the rehabilitation and restoration phase of DM, are as follows:

1. **Preparation of an alternate power supply plan:** Alternate healthy lines were identified, characteristically having the potential to act as a secondary source of power for adversely affected areas. This process reduced the outage time for the end consumer and allowed DISCOMs to prioritize the restoration of other impacted networks.

2. **Last price procurement from CPSUs/SPSUs:** Additional spares were procured from central public sector undertakings (CPSUs)/state public sector undertakings (SPSUs) at previously negotiated prices upon advance agreement with vendors.

3. **Approval of higher labour rates (up to 1.5x):** Approval granted for procurement of skilled labour at higher allowances to address skill gaps and shorten restoration periods.

4.2.2 Proposed recommendations

Table 4.2: Proposed recommendations in rehabilitation and restoration: summary

Theme of Intervention	Proposed Recommendations
Integration of Advanced Technology and Machinery	• Use of specialized machinery and equipment • Use of mobile substations to reduce the impact on business continuity • GPS-enabled workforce structuring
Capability and Capacity Development	• Competency mapping
Resource Mobilization	• Regional alliances and mutual aid agreements
Organizational and Operational Adaptations	• State-specific designs and specifications

1. Use of Specialized Machinery and Equipment

Current Practice	The restoration process is primarily workforce-driven for the power sector in the state. Many activities, such as pole erection, cable placement and stringing, among others, are still carried out manually. This, in turn, requires a large workforce, especially post-disaster, to commence restoration activities on time.
Challenges Faced	Manual processes are time-consuming, leading to delays in the recovery process. Prolonged power outages have an adverse impact on power utilities and communities at large.
Areas of Intervention	Using specialized and customized machinery such as pole erection machines, cable placers and boom trucks, among others, to restore damaged networks and components can minimize the impact on consumers through reduced power disruption durations.
Global Best Practices	The Saskatchewan Power Corporation[27] in Canada extensively used pole mounting machines (Digger Derrick) for the rapid erection of poles during restoration after the damage caused by the windstorm at Regina in 2021.

Expected Outcomes

- Reduction in restoration time
- Reduction in manual labour
- Lesser restoration workforce needed
- Reduction in operational losses due to lesser downtime

Approach

- Identification of vulnerable areas and allotment of workforce and resources accordingly
- Mobilization and pre-positioning of resources across impact areas
- Workforce training on usage and maintenance of specialized machinery and equipment

Implementation Timeline

- Up to 06 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 40–42 crores/US$ 5.6 million** (For each of the 45 DISCOM division offices across nine cyclone vulnerable districts – one bucket truck and two pole erection machines)

[27] Details available at
https://leaderpost.com/news/local-news/storm-knocks-80000-power-users-off-the-grid-in-sask

2. Use of Mobile Substations for Reduced Impact on Business Continuity

Current Practice	Restoration is carried out on a priority basis in the event of substation failure. Restoration typically takes two to five days, depending on the extent of damage.
Challenges Faced	Prolonged restoration periods result in mounting losses for consumers. Mobile and ready-to-deploy components must, therefore, be leveraged to temporarily restore power and ensure continuity.
Areas of Intervention	Specialized and customized machinery such as pole erection machines, cable placers and boom trucks, among others, should be used to restore damaged networks and components. This will help minimize the adverse consequences for consumers by reducing the power disruption periods.
Global Best Practices	National Grid,[28] the transmission operator of Saudi Electricity Company, deployed two mobile substations (mounted on a special trailer) for easy mobility and quicker deployment. Specification: 380 kV, 502 MVA (power capacity) by Siemens Energy Applications: • Weather and natural outages • Planned maintenance and remote operations • Forced outage repairs

Expected Outcomes

- Grid resilience for failures
- Flexibility in operation, maintenance and renovation mechanisms
- Agility for grid reinforcement projects
- Reduction in operational losses due to lesser downtime

Approach

- Identification of damaged substations
- Allotment of mobile substation for power continuity
- Mobilization of available substations to the damaged areas
- Simultaneous restoration of primary substation

Implementation Timeline

- Up to 06 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 7–9 crores/US$ 1.2 million** (45 division offices across vulnerable districts-one per office)

[28]Siemens. 2017. Siemens will improve resilience of the Saudi Arabian power grid
Details available at https://press.siemens.com/global/en/pressrelease/siemens-will-improve-resilience-saudi-arabian-power-grid-mobile-substations, last accessed on 9 January 2022

3. GPS-Enabled Workforce Structuring

Current Practice	Post-disaster, control rooms have to search for teams (gangs) that are closely positioned to the reported sites (complaints regarding damage). Due to the lack of direct connectivity and technological interventions, workforce allocation for restoration purposes is done through a series of communication channels, which can be time-consuming.
Challenges Faced	Time spent locating teams and establishing communication slows down the associated restoration processes.
Areas of Intervention	A restoration workforce with GPS-enabled tracking would allow control rooms to effectively locate and deploy teams to damaged areas, depending on their proximity and availability.
Global Best Practices	Fleet tracking is one of the most prominent GPS applications for tracking resources and managing on-field operations. It is commonly used in transport and logistics companies wher tracking drivers and vehicles is critical for business functions. Workforce tracking can also be used during the restoration phase, so locating the workforce on time would reduce the time consumed on each operation (site) and ensure easy mobilization to the next assignment.

Expected Outcomes

- Reduced response time
- Real-time workforce personnel tracking system
- Quicker mobilization of workforce
- Greater convenience in terms of team deployment and giving directions for the next spot

Approach

- Handheld GPS devices for each of the restoration workforce team (gang) leaders
- GPS-enabled tracking of team members
- Locating the nearest available team(s) after a customer registers a failure complaint at the control room/helpdesk
- Intimating the team(s) regarding failures and sending the co-ordinates for seamless coordination

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **INR 40–50 lakhs/US$ 0.05 million** (Garmin GPS Navigation Etrex10 for 500 gangs for restoration workforce, one device per gang)

4. Regional Alliances and Mutual Aid Agreements

Current Practice	A skilled workforce from Andhra Pradesh and Telangana was mobilized for additional support during restoration, post-Fani. However, the resource-sharing process lacked agreement on corresponding documentation and pre-defined trigger parameters.
Challenges Faced	Given the scale of damage caused in the past, Odisha's power sector has faced a scarcity in terms of a skilled workforce to commence response and restoration activities. Resource-sharing with neighbouring utilities and states would, therefore, ensure a timely supply of skilled workforce.
Areas of Intervention	Memorandum of understanding /contracts are required to formalize resource sharing (restoration workforce, equipment and spares) with utilities located across neighbouring states and regions.
Global Best Practices	Over 2000 public power utilities are part of the American Public Power Association (APPA)[29] mutual aid programme, which leverages local, state and regional contracts and agreements for mutual aid.

Expected Outcomes

- Improved post-disaster response
- Increased access to skilled workforce and equipment
- Reduced cost of operation due to workforce optimization
- Reduced operation and maintenance and related costs due to equipment sharing

Approach

- Competency mapping of resources across utilities
- Pre-identified resources for agreement fulfilment
- Increased allowances to encourage participation (up to 1.5x over the allowances fixed by Odisha, including food, stay and transport)

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- **Not applicable**

(Dependent on the government-to-government or utility-to-utility transaction for Memorandum of understanding; resource sharing cost INR 7–8 crores)

[29]Details available at at https://www.publicpower.org/about, last accessed on 9 January 2022

5. Competency Mapping

Current Practice	Workforces are deployed based on the availability and historical performance of personnel during restoration processes. Inadequate opportunities and mandates for skill development have led to generalizing skills in the longer term.
Challenges Faced	The limited availability of skilled labour compelled the power sector to procure resources from nearby states at inflated prices. The time consumed in procuring and mobilizing skilled workforces led to a delayed restoration process.
Areas of Intervention	Training needs assessment of the workforce and competency mapping of the available workforce as per their expertise or experience in past disasters will be critical for impactful restoration processes.
Global Best Practices	Atlantic City Electric has an Emergency Management Department with a clearly defined second role programme. All employees have defined roles and responsibilities, and resource allotment is based on their skills and capacities.

Expected Outcomes

- Defined roles and responsibilities in the event of a disaster
- Well-defined areas of expertise for every resource
- Ensures that the workforce deployed in a disaster-affected region is attuned to associated risks

Approach

- Skill mapping of workforces at each substation
- Workforce classification under action groups
- Identification of skill gaps and capacity-building needs
- Continuous monitoring of workforce competency

Implementation Timeline

- Up to 3 months

Stakeholder Ownership

- Utility (HR)

Estimated Cost

- **INR 40–45 lakhs/US$ 6 million** (Consulting assignment)

6. State-Specific Designs and Specifications

Current Practice	Restoration activities of damaged infrastructure are undertaken based on national standards defined by the Central Electricity Authority (CEA).
Challenges Faced	The fund allocation process takes considerable time due to multiple stages of approvals, which, in turn, delays the entire disaster management process. Moreover, funds allocated in the past have been insufficient to manage expenses to cover the large-scale damage and losses caused to the power sector.
Areas of Intervention	State-specific designs need to be created to enhance the system's capacity to withstand disasters at the local level. Central-level specifications can be considered for the first phase of the analysis, with amendments for additional strengthening wherever required.
Global Best Practices	Islands in the Caribbean follow a territorial approach to carry out a decentralized DM process, with each country developing its own disaster risk mitigation plans and technical guidelines. Such a territorial approach also includes decentralizing the risk management process.

Expected Outcomes

- Reinforced and improved design of components to withstand future occurrences of disaster even with higher impact
- Minimal or no monetary loss to the power utility due to damages and operational losses

Approach

- Specifications in the state design manual can be included in three stages:
  - Adapting existing specifications
  - Inserting missing specifications
  - State specification based on hazard and vulnerability assessment

Implementation Timeline

- Up to 6 months

Stakeholder Ownership

- Department of Energy

Estimated Cost

- **INR 40 lakhs/US$ 5.3 million** (Consulting assignment)

4.3 Recovery

The primary objective of the recovery phase is long-term development. It focuses on resuming normal operations to pre-disaster levels through two integral stages: short- and long-term development. Short-term recovery focuses on resuming power supply to affected areas by replacing or installing new infrastructure in damaged areas. Long-term recovery aims to enhance power infrastructure resilience by 'Building Back Better', ultimately improving the capacity to withstand the increasing impact of disasters.

4.3.1 Learnings from Odisha power sector

1. Community-based assistance for power restoration: Communities were engaged in restoration processes by leveraging trained local volunteers. Volunteers were trained in specific areas and skills (hazard vulnerable) to effectively participate in restoration activities in the wake of a disaster.

2. Materials and workforce mobilized from ongoing sites: Skilled workforce, equipment and spares were mobilized from ongoing power sector development projects (for e.g. Odisha Distribution System Strengthening Programme (ODSSP). This enabled easy access to a skilled workforce and spare parts to address additional requirements during the restoration of damaged networks.

3. Deployment of emergency restoration towers: Emergency restoration towers were deployed to temporarily bypass the disrupted transmission tower. This reduced downtime and supported the restoration of damaged towers in parallel.

4.3.2 Proposed recommendations

Table 4.3: Proposed recommendations in recovery actions: summary

Theme of Intervention	Proposed Recommendations
Adherence to Existing Specifications	• Elevation of the substation plinth or mount over the highest flood levels
Integration of Advanced Technology and Specifications	• Replacement of existing substations with GIS/submersible substations • Replacement of low-tension (LT) poles with improved design and reinforced materials
New Financing Constructs	• Tariff included an additional cost for resilience • Contingency credit finance • Parametric insurance and catastrophic (CAT) bonds

1. Adherence to Existing Specifications

Current Practice	Critical guidelines (installation and operational) are skipped to complete restoration processes in a time-sensitive schedule. This leads to failures when disasters strike again, raising serious doubts about quality management.
Challenges Faced	Repeated component failures lead to increased replacement and repair costs, which, in turn, can lead to higher chances of component failures, resulting in power disruptions.
Areas of Intervention	Elevating the substation plinth or mount level above the highest flood levels based on historical evaluations will minimize the risk of substation inundation during a storm surge.
Global Best Practices	Following Superstorm Sandy and the extensive damage done to regional distribution systems and substations, the Public Service Electric and Gas Company (PSEG)[30] approved over US$ 1 billion for hardening and modernizing electric and gas infrastructure that included US$ 600 million towards the elevation of 29 substations damaged during Sandy by 1 to 2 feet above Federal Emergency Management Agency (FEMA) flood levels.

Expected Outcomes

- Reduction in substation failures due to inundation
- Futureproofing of substations against increasing disaster risks
- Reduced impact on power users

Approach

- Historical assessment of flood levels across the region
- Identification of substations 'at risk' in the specified zone
- Assessment of existing elevation levels of substations
- Elevation of substations 'at risk' to mitigate the risk of floods

Implementation Timeline

- Up to 36 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- INR 9–10 crores/US$ 1.3 million (113 of 820 identified transformers in the flood-prone zone)

[30]Details available at
https://nj.pseg.com/newsroom/newsrelease36

2. Replacing Vulnerable Components: GIS Substations

Current Practice	Air-insulated substations tend to fail during storm surges and inundations. Substation failures have a large-scale impact on power supply continuity in terms of cost and operations. Taking into consideration the flood and cyclone events, the arrangement of transformers would enhance the resiliency of the power sector.
Challenges Faced	Large-scale power disruptions are caused by inundations during storm surges after the passage of cyclones due to transformer failures.
Areas of Intervention	Existing substations can be replaced with GIS/submersibles across zones and overhead lines vulnerable to floods and storm surges.
Global Best Practices	Kerala State Electricity Board (KSEB)[31] has commenced the operation of a 220 kV GIS substation in Kochi to address substation inundation due to frequent storm surges and flooding. The project is estimated to cost approximately INR 130 crores.

Expected Outcomes

- Reduction in substation failures due to inundation
- Futureproofing substations against increasing disaster risks
- Keeping plinth of substations above highest flood levels

Approach

- Historical assessment of flood levels across the region
- Identification of substations 'at risk' in the specified zone
- Procuring GIS substations
- Replacing existing substations with GIS substations

Implementation Timeline

- Up to 36 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- INR 4380 crores/US$ 584 million (Replacement cost for 438 of 820 vulnerable 33/11 kV substations)

[31] Sreejith, T. J. (n.d.). KSEB's new power projects in Kochi get rapid completion. Mathrubhumi.
Details available at
https://english.mathrubhumi.com/news/kerala/kseb-s-new-power-projects-in-kochi-get-rapid-completion-1.5413914, last accessed on 9 January 2022

3. Reinforcing the Existing Infrastructure: **LT Poles**

Current Practice	Pre-stressed cement concrete (PSC) poles currently in use are significantly heavier than their advanced counterparts and at a disadvantage against high wind speeds. Poles function as the backbone of the overall distribution system. Therefore, reinforcements would enhance their resilience and the broader power sector.
Challenges Faced	Uprooted PSC poles would impact the power supply to end consumers. Hence, protecting distribution infrastructure is of critical concern. This can be achieved by adopting components with improved designs or by replacing existing components with improved materials.
Areas of Intervention	LT poles can be replaced with improved designs and reinforced materials, such as spun concrete poles, to withstand high wind speeds.
Global Best Practices	Andhra Pradesh initiated the installation of spun concrete poles[32] to enhance the resilience and reliability of electric poles during a disaster. Rochester Gas and Electric (RG&E) and New York State Electric and Gas Corp (NYSEG) replaced 900 old wooden poles with fibre-reinforced polymer poles in Rochester city after a windstorm in 2017.

Expected Outcomes

- Increased strength compared to existing PSC poles
- Reduced failure leading to reduced operation and maintenance expenses
- Reduced impact on power users

Approach

- Replacement of poles in remote and moderate wind speed zones and 50–60 km away from the coastal belt
- Use of spun concrete poles in reconstruction areas, post-disaster

Implementation Timeline

- Up to 24 months

Stakeholder Ownership

- Utility (Operations)

Estimated Cost

- INR 240 crores/US$ 32 million

[32]Rao V Kamalakara. 2019. Spun Poles to soon 'uproot' electric poles in coastal districts of Andhra Pradesh. The Times of India. Details available at https://timesofindia.indiatimes.com/city/visakhapatnam/spun-poles-to-soon-uproot-electric-poles-in-coastal-dists/articleshow/70707102.cms, last accessed on 9 January 2022

4. Tariff Included Additional Cost for Resilience

Current Practice	Currently, funds required for restoration and recovery processes are procured from State Disaster Relief Fund (SDRF), state budget allocations, and grants and aid received from various authorities. These funds are used to procure spares and equipment, meet workforce wages and cover other operational expenditures.
Challenges Faced	Allocating these funds takes considerable time owing to the multiple approval stages, which delay the entire DM process and restoration phases. Moreover, funds have historically been insufficient to manage expenses due to large-scale damage and losses caused to the power sector.
Areas of Intervention	Provisions should include additional costs towards building disaster-resilient power systems via tariffs such as a power cess.
Global Best Practices	India's national budget for 2018-19 proposed a levy on road and infrastructure of INR 8 per litre on fuel, which was updated to INR 18 per litre in 2021–22. The cess collected is directed to the Central and Road Infrastructure Fund, which focuses on the development and maintenance of national highways, rural roads, inter-state roads, railway infrastructure and other infra projects.

Expected Outcomes

- Collected funds used for capacity building, material building and infrastructure upgradations
- Reduced load on DISCOMs and the Department of Energy for funds management
- Hike in cess by 1p/unit can give access to INR 28 crore+ in the Financial Year 2022

Approach

- Assessment of fund requirements based on estimation and forecasting
- Adapting the fund requirements to tariff loading on customers
- Preparation of a business case for regulatory approval

Implementation Timeline

- Up to 6 months

Stakeholder Ownership

- Department of Energy

Estimated Cost

- Not applicable

5. Contingency Credit Finance

Current Practice	Currently, funds required for restoration and recovery processes are procured from the state disaster relief fund, state budget allocations, and grants and aid received from various authorities. These funds are used to procure spares and equipment, meet workforce wages and cover other operational expenditures.
Challenges Faced	Fund allocation consumes considerable time owing to the multiple stages of approvals, which delay the entire DM process. Moreover, funds have historically been insufficient to manage expenses due to large-scale damage and losses caused to the power sector.
Areas of Intervention	Contingent credit financing with a Deferred Drawdown Option (DDO) from the International Development Association (IDA) can enable immediate liquidity for reconstruction.
Global Best Practices	In the wake of tropical storm Washi in 2011, the Philippines[33] received US$ 500 million from the World Bank's Development Policy Loan (DPL) with Catastrophe Deferred Drawdown Option (Cat-DDO) for recovery and reconstruction.

[33] World Bank Group. 2021. Philippines: development policy loan
Details available at
https://www.worldbank.org/en/news/press-release/2021/12/21/philippines -world-bank-approves-additional-funding-for-more-vaccines#:~:text=The%20funding%20builds%20on%20the,out%20of%20the%20vaccination%20program, last accessed on 9 January 2022

Expected Outcomes

- Immediate access to funds (up to US$ 500 million/0.25% GDP)
- Reduced dependency on donor assistance and government aid
- Increased focus on long-term disaster resilience

Approach

- Creation of utility-owner disaster fund
- Allocation of at least 1.5 percent of annual revenue (recommended by the Ministry of Power)
- Pre-disaster disbursement of cash for timely response actions

Implementation Timeline

- Up to 3 months

Stakeholder Ownership

- Utility (finance)

Estimated Cost

- Not applicable

6. Parametric Insurance and CAT Bonds

Current Practice	Restoration and recovery funds are primarily sourced from the state disaster relief fund, state budget allotments and other grants and aids from numerous organizations. These financial resources are employed to secure replacement parts and other equipment, renumerate work-force wages and manage related operational expenses.
Challenges Faced	The distribution of funds takes a substantial amount of time due to multiple approval stages, leading to delays in the DM process. Inadequate historical funding has been insufficient to cover significant expenses from extensive damage and losses in the power sector.
Areas of Intervention	Risk transfer-based financing instruments for access to large-scale funds during reconstruction in the aftermath of a disaster can be explored via parametric insurance and CAT bonds.

Global Best Practices

Anguilla Electricity Company Limited (ANGLEC)[34] relies on parametric insurance facilitated by the Caribbean Catastrophe Risk Insurance Facility (CCRIF). The product aims to limit the fiscal impact of cyclones by providing financial liquidity to electric utility companies when a policy is triggered, covering direct damage to transmission and distribution components. ANGLEC was severely impacted by Hurricane Irma in 2017, costing more than XCD 40 million to restore.

Expected Outcomes

- Possibility to provide coverage for difficult-to-model losses
- Flexibility to use the fund proceeds to cover any economic loss
- Increased focus on long-term disaster resilience

Approach

- DISCOMs individually design insurance models based on the vulnerability of their assets to disaster
- Analysis of available and measurable data (e.g., wind speeds) to create a reliable and creditable index for trigger points
- Design of insurance by mutually structuring a bespoke policy

Implementation Timeline

- Up to 03 months

Stakeholder Ownership

- Utility (finance)

Estimated Cost

- INR 24 crore/US$ 3.2 million (Parametric Insurance); INR 230 crore (CAT bonds at 6% coupon rate); Financing of INR 1,200 crore (socio-economic impact of Cyclone Fani)

4.3.3 Final Insights and Path Ahead

The primary objective of the proposed recommendations is to improve, streamline and institutionalize the sequence of response actions to be undertaken immediately after a disaster by leveraging technology, automation, SOPs and improved machinery.

[34]Details available at https://www.ccrif.org/node/12272?language_content_entity=en

Implementing the above recommendations would have an incremental impact by aiding a prompt return to business via multiple strategies. These measures would provide increased control and visibility over processes, allowing for quicker decision-making in a time-sensitive schedule.

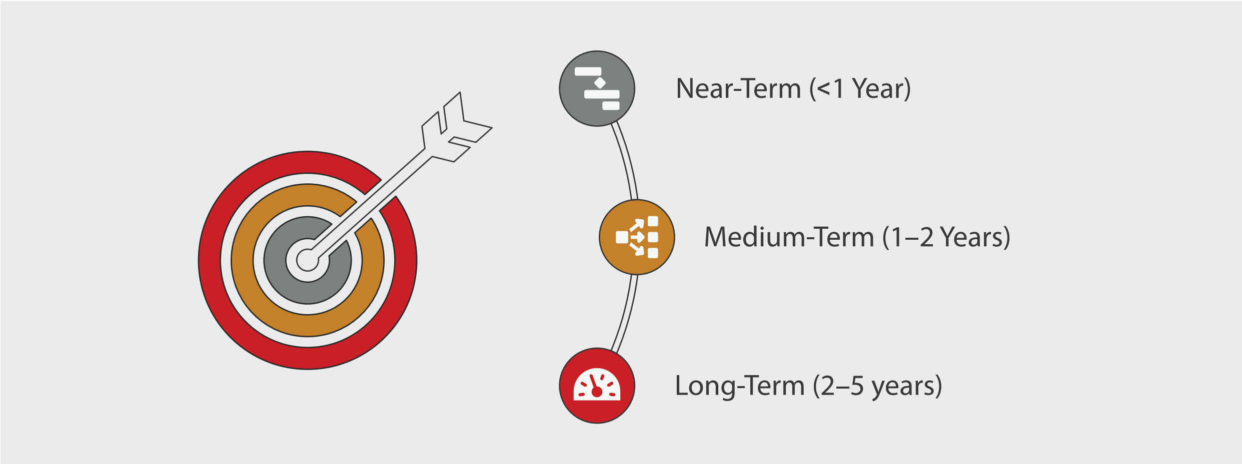
Integrating the increasing impact of climate hazards into design would prevent infrastructure from crumbling in the face of disasters in the near term and protect the entire value chain from impact over a longer tenure. As a result, this approach would help utility and power consumers save a significant amount over sustained periods.

Annexure 13 showcases one of the key advisories issued by CDRI to stakeholders across the power sector to help them in preparing for the cyclone season.

5 Roadmap and Implementation Strategies

5. Roadmap and Implementation Strategies

Transitioning to a best-in-class disaster-resilient power system can be defined as a three-stage process based on implementation and relevance vis-à-vis the existing system:



All the recommendations mapped across the disaster management (DM) process were classified according to the implementation stages (see Table 5.1). This classification was used to develop a holistic roadmap for enhancing the Odisha power sector's disaster resilience.

The actions are categorized based on their impact (high/medium/low) and corresponding investment requirements (high/medium/low). While impact assessment and classification under high/medium/low can be subjective, investments under INR 10 crores can be categorized as low; between INR 10 and INR 500 crores as medium; and above INR 500 crores can be considered high investments.

Table 5.1: Implementation road map for enhanced disaster resilience in Odisha's power sector

Stakeholders	Near Team (<1 Year)	Medium Team (1-2 Years)	Long Team (2-5 Years)
Energy Department	» Formation of detailed SOP » Policy adaptation » IT enabled dashboard	» Digital knowledge management portal » State specific design specifications » Joint mock drills	
Regulatory Authority	» Improved governance structure		

Table 5.1: Implementation road map for enhanced disaster resilience in Odisha's power sector

Stakeholders	Near Team (<1 Year)	Medium Team (1-2 Years)	Long Team (2-5 Years)
Utility (Operations)	» Satellite phones for improved communication » Transportation via Helicopter » Spares bank » Regional alliances	» GIS mapping of networks » GPS enabled workforce structuring » Drone assisted damage assessment » Mobile substation	» Outage management system » Adherence to existing specifications » GIS substations » Spun concrete poles » Specialized machineries for restoration
Utility (Finance)	» Liquidity funds » Parametric insurance & CAT bonds	» Contingency credit finance	
Utility (HR)		» Competency mapping	

5.1 Implementation Strategy

Stakeholders	Action log	Months																			
		3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	
Department of Energy	Formulation of detailed SOP	■	■																			
	Policy Adaptation	■	■																			
	IT-Enabled Dashboard	■																				
	Digital Knowledge Management Portal				■																	
	State-Specific Design Specifications					■	■															
	Joint Mock Drills		■																			
Regulatory Authority	Improved Governance Structure			■																		
Utility (Operations)	GIS Mapping of Networks					■	■	■	■	■	■	■	■	■								
	Spares Bank	■	■																			
	Satellite Phones for Improved Communication		■	■																		
	Regional Alliances			■																		
	Transportation via Helicopter				■																	
	GPS-Enabled Workforce Structuring					■																
	Drone-Assisted Damage Assessment				■	■																
	Mobile Substation					■	■															
	Specialized Machinery for Restoration					■	■															
	Outage Management System					■	■	■	■	■	■	■	■	■	■	■	■	■				
	Adherence to Existing Specifications								■	■	■	■	■	■	■	■	■	■	■	■	■	■
	GIS Substations								■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Spun Concrete Poles					■	■	■	■	■	■	■	■	■								

Stakeholders	Action log	Months																				
		3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	
Utility (Finance)	Parametric Insurance	Near Term																				
	Liquidity Funds		Near Term																			
	Catastrophe (CAT) Bonds			Near Term																		
	Contingency Credit Finance				Long Term																	
Utility (HR)	Competency Mapping				Medium Term																	

Near Term   Medium Term   Long Term

5.2 Near-term Activities

Near-term activities can be integrated into the system immediately after a preliminary evaluation and feasibility assessment. Although these activities require low investment, they are known to produce high/medium intensity results in terms of the final impact. Following are some key recommendations for a near-term action plan:

1. State- and utility-level policies to strengthen infrastructure resilience: Amendments across policies to integrate disaster resilience into the existing framework would require a detailed study of current policies, a benchmarking study for global utilities and documentation of updated policies for stakeholder approval. The assignment can take approximately 6 months to complete and will require an estimated INR 2 crores for consulting services

2. Governance structure to acknowledge/oversee investments and projects for building resilience across energy utilities: Considering an overall timeline of 3 months and an investment amount of INR 40 lakhs, integrating a regulator into the project approval process for disaster resilience will qualify as a near-term activity.

3. Disaster liquidity fund within the utility (with 1.5% share from utility revenue): Reserve funds for liquidity qualify for the near-term as the estimated time for implementation can be less than three months (with minimal or no investment).

4. IT-enabled dashboard: Deploying an IT-enabled dashboard would require a timeline of approximately 3 months, including tool deployment, system integration and workforce training, among others, with a total outlay of INR 60 lakhs. Based on these parameters, deploying the IT-enabled dashboard is a near-term activity.

5. Regional and mutual alliances: Regional alliances for resource-sharing would involve states signing a memorandum of understanding to share a set of pre-determined resources in the event of a disaster. The deployment can take up to 3 months. Hence, regional and mutual alliance formation qualifies as a near-term activity.

5.3 Medium-term Activities

Medium-term activities potentially carry a high degree of impact but require a medium amount of investment (typically ranging from INR 10 to INR 100 crores). These activities also tend to have less than two years of lead deployment time. The proposed recommendations include a detailed assessment of the requirements, procurement of materials, agreements with partners/stakeholders (if any) and respective capability/capacity building. Following are the key recommendations for a medium-term action plan:

1. GPS device and satellite communication phone-enabled restoration gangs: The timelines for design finalization, procurement, distribution and workforce training are estimated to be more than a year, with a total cash outlay of INR 7 crores. However, the impact on system resilience is expected to be medium, thereby qualifying as a medium-term activity.

2. Helicopter-based transportation of resources and workforce: The deployment timeline for helicopter based transportation is indefinite. This is because the demand for service subscriptions will arise only during a disaster. However, the empanelment of vendors with pre-determined rate charts would expedite the deployment process. The estimated timeline for this process is up to 6 months, with a total outlay of INR 1.5–2 crores.

3. Drone-assisted damage assessment: The process of assessing aerial damage after a disaster using drones involves three main stages finalizing the design, procuring the necessary equipment and providing training. The estimated deployment time is 6 months, with an outlay of INR 20–22 crores. This qualifies as a near-term activity by taking into consideration the cyclone frequency on India's east coast.

4. Parametric insurance, CAT bonds and contingent financing for increased post disaster liquidity: Parametric insurance and CAT bonds are medium-term considerations because the implementation time is approximately more than 1 year. An ideal process would include an agreement between the International Development Association (IDA) and the utility energy department to disburse funds based on a specific (agreed) trigger. The parametric insurance premium and the CAT bond coupon rate can be finalized based on an agreement between utilities and the IDA. CAT bonds and parametric insurance ensure liquidity immediately after a disaster to carry out response and restoration processes. Thus, these are defined as high-impact activities.

5.4 Long-term Activities

Long-term activities carry a potential for high impact but are also capital-intensive (i.e., incurring an expenditure of over INR 500 crores and above) and have a lead deployment time of more than two years (up to five years). The proposed recommendations call for a detailed assessment of the requirements, infrastructure development and system integration of network components in digital tools.

Key recommendations for a long-term action plan:

1. GIS coding of downstream networks: GIS coding of network assets consists of geographical tagging, deploying a digital asset management tool, system integration of network assets in the asset management tool and going live. The estimated deployment timeline for GIS coding across the state is 36 months, and the expected cash outlay is INR 200 crores.

2. Technology-enabled vegetation management: The estimated timeline for deploying technology solutions for vegetation management is up to 1 year. GIS mapping of the entire network is a prerequisite. This is followed by the geographical tagging of assets, system integration of the solution, hyper-care and going live.

3. Leveraging outage management system: Deployment of outage management for failure identification would require smart meters with advanced metering infrastructure (AMI). The consolidated project cost and timelines for all the power customers (9 million) are estimated to exceed INR 8,000 crores (US$ 1.06 billion), with an estimated deployment time of up to 36 months. Therefore, this measure classifies as a long-term recommendation due to high investment and long deployment tenure.

6 Way Forward

6. Way Forward

1. Resilience-based policy adaptation: Odisha's power sector needs a state-level policy to strengthen its resilience and drive changes in terms of financial limits, financing schemes, operational processes, procurement processes, workforce and skill-building.

2. Detailed SOPs for key activities as a part of the disaster management process: SOPs for disaster restoration and reconstruction work need to be in place, focusing across multiple levels on procurement, labour deployment, workmanship for commissioning and erection, operation and maintenance post-handover, and preventive maintenance.

3. Institutionalizing public-private partnerships for disaster management: Segregated roles within the power sector must be established immediately to effectively manage prevention and reconstruction activities. This is unlike the shared ownership and responsibilities between energy and utility departments that have always existed.

4. Integration of IMD, OSDMA and DISCOMs for an automated Early Warning System (EWS): Actively collaborating with IMD could facilitate in designing and potentially piloting an EWS to enhance the accuracy of a landfall's location and its potential impact on power infra-assets.

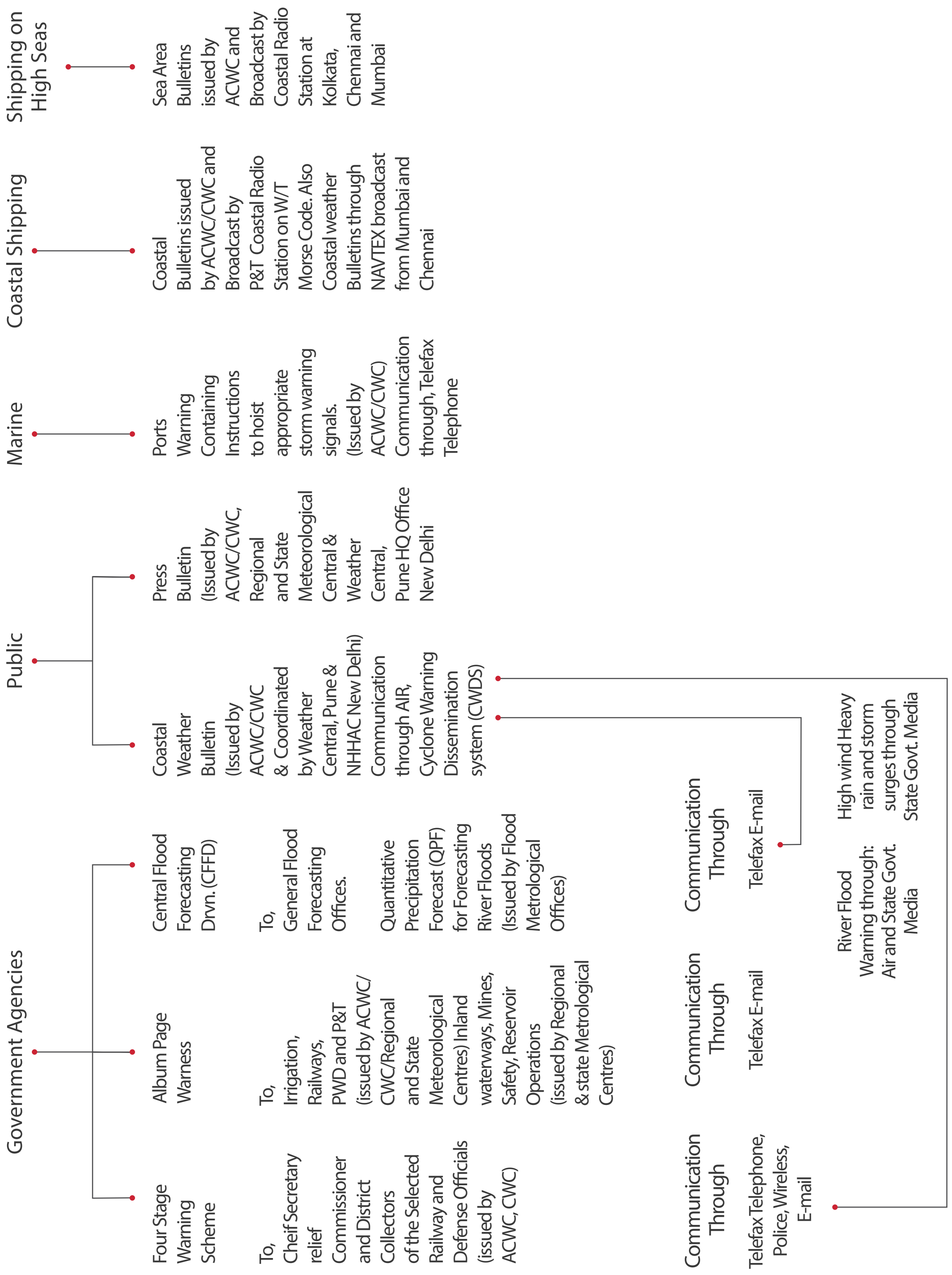
5. Long-term planning for infrastructure resilience: A long-term roadmap focussing on resilience goals should be developed (for instance, spanning a period of 20 years). This plan could act as a yardstick for annual updates and successive annual strategies.

6. Regulatory inclusion for a robust disaster resilience foundation: While state energy departments, DISCOMs and TRANSCOs are the implementing agencies to enhance on-ground disaster resilience, OERC has the prime responsibility of enabling resilience specific action items as the regulatory authority. Involving the regulator in the process of enhancing the sector's disaster resilience will include, but not be limited to, tasks such as approving, monitoring and ensuring that disaster resilience remains an integral part of all power infr structure construction projects. OERC's involvement would significantly improve the quality and timescale, and cost-effectiveness of these efforts.

Annexures

Annexure 1: Standard Operating Procedures for Cyclone Warning Dissemination by India Meteorological Department

Table 7.1 Dissemination of the cyclone warnings



Annexure 2: Post-Cyclone Fani Grid Restoration

Date	Event
3rd May	• 220kV New Duburi-Paradeep CKT-II charged • 132 kV Paradeep Grid-Paradeep Port CKT-I & II charged • 132kV Paradeep Grid-PPL CKT-I charged • 132kV Paradeep Grid-IESSAR CKT-I charged • 220kV Paradeep Grid-IESSAR CKT-II charged • 132kV Paradeep Grid-Jagatsinghpur Line charged Jagatsingpur restored • 220kV Paradeep Grid-IOCL charged
4th May	• 220kV New Duburi-Paradeep CKT-I charged • 132 kV Paradeep-IFFCO CKT-II charged • 132kV Paradeep -Kendrapara CKT-II charged Kendrapara restored • 132kV Paradeep Kenrapara CKT-I charged
5th May	• 132kV Jagatsinghpur-Cuttack line charged Cuttack restored • 220kV Cuttack-Bidanasi line charged • Chandaka availed p/s from CHOUDWAR on 132 kV Chandaka-BPPL • 220kV Chandaka-Chandaka 'B' CKT charged from Chandaka-BPPL • 132kV Chandaka-BBSR CKT-I charged • 220kV Meramundali-Bidanasi charged • 132kV Chandaka-Ransinghpur line charged • 132kV Chandaka B-Unit 8, Bhubaneswar line charged through UG cable
6h May	• 132kV Cuttack-Bhubaneswar charged

Date	Event
7th May	• 220kV Mendhasal-Chandaka CKT-II charged from Mendhasal • 400kV Meramundali-Mendhasal Line charged • 315kV MVA ICT-I at Mendhasal Grid charged • 400kV Meramundali-Pandiabili charged • 132kV Bhubaneswar-Chandaka CKT-II, Bhubaneswar
8th May	• 220kV Mendhasal-Chandaka 'B' - Chandaka CKT-IV charged from Mendhasal
11th May	• 132kV Bhubaneswar-Phulnakhara Line charged • 132/33kV Grid S/s Phulnakhara got power supply from Bhubaneswar • 132kV Cuttack-Phulnakhara Line charged
13th May	• 132kV Ranasinghpur-Kesura Line charged • 132/33kV Grid S/s Kesura got power supply from Chandaka
14th May	• 132kV Chandaka-Nimapara Line charged • 132/33kV Grid S/s Nimapara got power supply from Chandaka • 132/33kV Nimapara-Puri Line charged through 8 nos. of ERS Tower • 132kV Grid S/s Puri got power supply from Nimapara • 132kV Nimapara-Konark Line charged • 132/33kV S/s Konark got power supply from Nimapara
15th May	• 132kV Samagara LILO charged by shorting from 132kV Nimapara-Puri Line • 220/132/33kV Grid S/s, Samagara got power supply

Date	Event
16th May	• 132kV Kesura-Nimapara Line charged from Kesura
18th May	• 220kV Mendhasal-Chandaka CKT-III charged
19th May	• 132kV Puri-Shamuka Line charged through 4 nos. of ERS Tower • 132/33kV Shamuka Grid got power supply
20th May	• 220kV Mendhasal-Chandaka CKT-IV strung on original Tower, ERS removed
29th May	• 220kV Mendhasal-Chandaka CKT-I charged on new Tower, ERS removed • 220kV Narendrapur-Atri CKT-I charged on new towers, ERS removed • 132kV Bidanasi-Choudwar Line and 132kv Bidanasi Chandaka Line charged on new towers inside River Mahanadi
31st May	• 220kV Narendrapur-Atri CKT-I permanent restoration complete, ERS removed
9th June	• 132kV Chandaka -Mendhasal charged on new towers • 132kV Khurda-Shamuka-Puri charged on new towers ERS removed

Figure A2.1: 33/11 kV substation mapping (wind hazard)

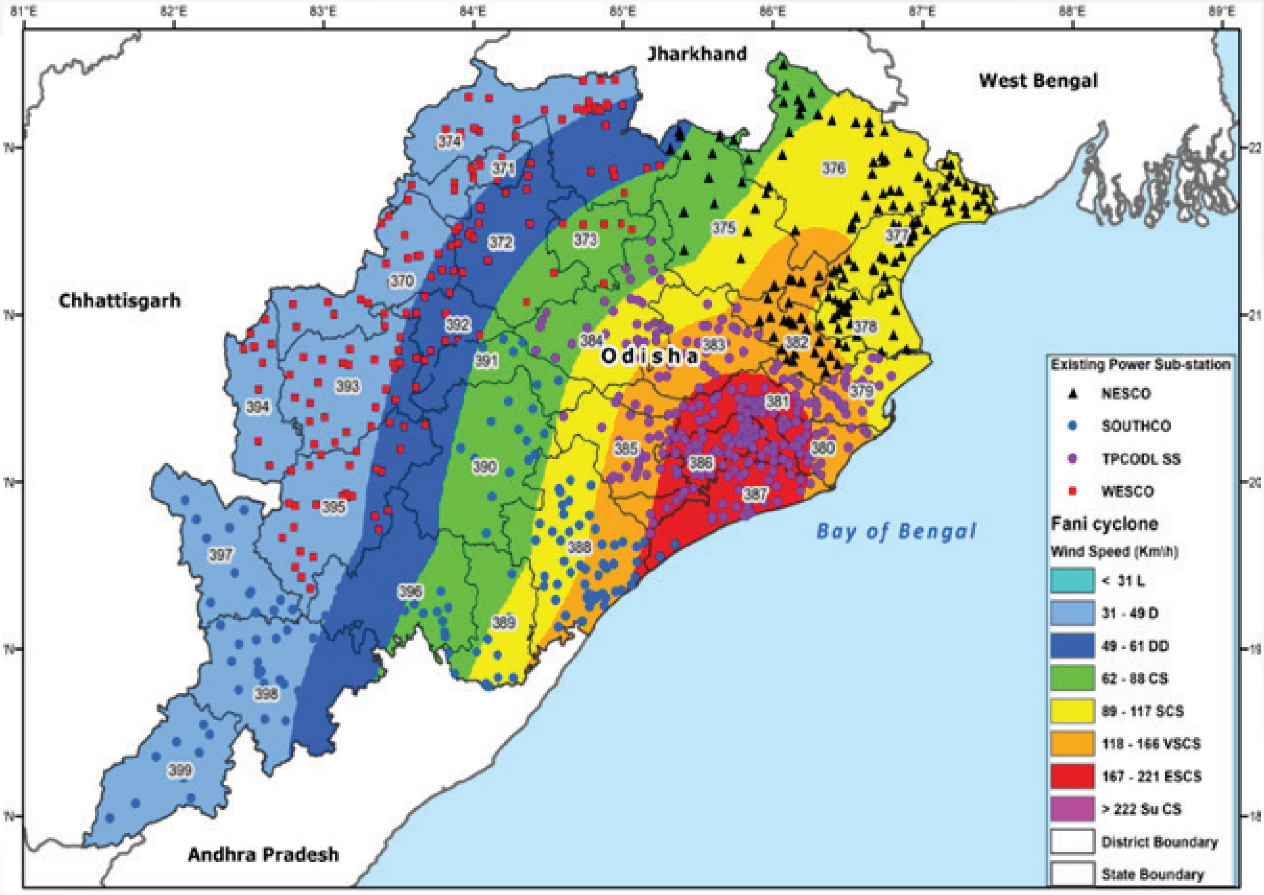
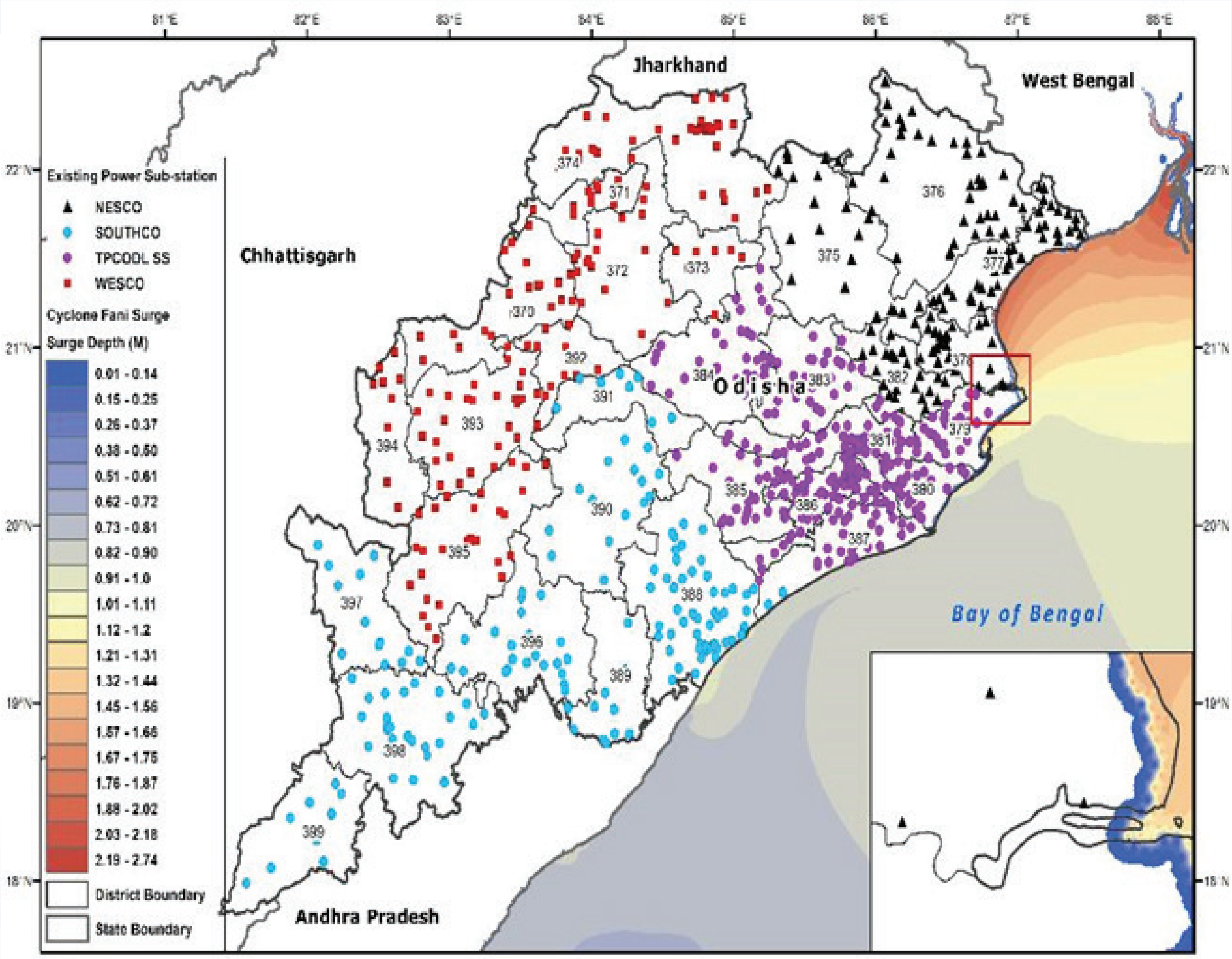


Figure A2.2: 33/11 kV substation mapping with respect to Cyclone Fani (surge hazard zones)



Annexure 3: Community Survey (Demographic Overview)

Puri

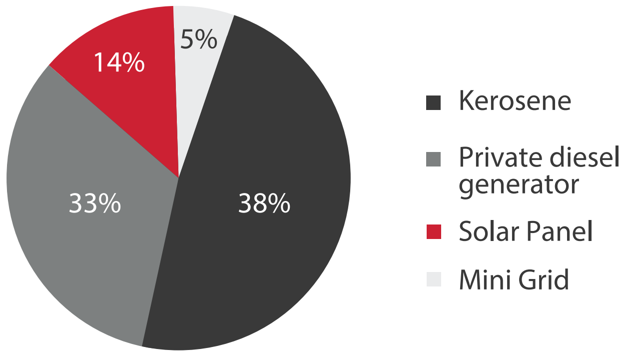
16 Villages | 5 Blocks

- Male: 19,252
- Female: 27,510
- Households: 9,242
- BPL: 40.40%
- SC: 32.24%
- Others: 67.86%
- 57.14% population dependent on agriculture
- Physically Challenged: 7,174
- 1,337 mm rainfall/year

Figure A3.1: Community survey results: 90% of the population

46.3% Impacted During Fani

Other Sources of Electricity | 90% of Population



Jagatsinghpur

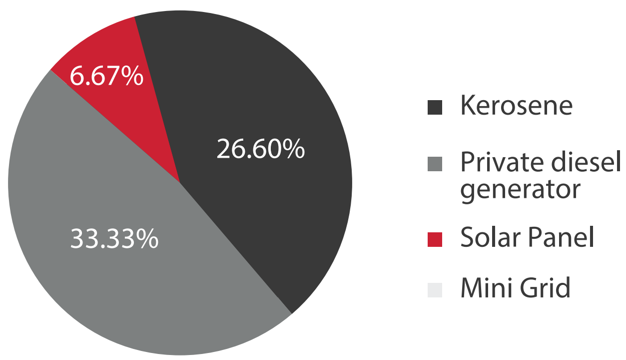
12 Villages | 3 Blocks

- Male: 16,447
- Female: 15,472
- BPL: 46.65%
- SC: 32.74%
- Others: 67.26%
- 73.3% population dependent on agriculture
- Physically challenged: 394
- mm rainfall/year

Figure A3.2: Community survey results: 66% of the population

11.45% Impacted During Fani

Other Sources of Electricity | 66% of Population



Annexure 4: Community Survey (Multi-Tier Analysis)

It is important to assess Odisha's disaster management from consumer perspective, as communities are the most severely affected by disasters. Implementing a multi-tier framework, therefore, would help to assess the community survey's results and present the findings in a structured manner.

Impact

- Almost all primary schools were affected with 30 percent being severely damaged.
- Around 75 percent of villages experienced food shortages.
- About 58 percent of villages had no public transport for more than a week.
- Approximately, 3000 fishermen were injured. Furthermore, 48 percent of villages suffered from a lack of clean drinking water for more than 15 days.
- Around 45 percent of people reported unemployment and poverty.
- About 44 percent of villages had disrupted telecommunication lines.

Response and Relief

- Priority assistance was delivered to marginalized communities and vulnerable groups, including Dalits, women, children, the elderly, people with disabilities and religious minorities in over 70 percent of villages.
- Immediate health aid was provided to 50 percent of villages for their community members.
- More than 8000 people were evacuated.
- Immediate food and water provisions were available in 83 percent of villages.
- Health camps were set up in 50 percent of villages.

Preparedness

- It was found that 58 percent of villages had structural measures (e.g., embankment, flood barriers, etc.) in place to protect their area from likely natural hazards such as floods and cyclones.
- Around 36 percent of villages had their own disaster management plans.
- Only seven percent of villages were aware of helpline number(s).
- Around 44 percent of villagers participated in awareness events specific to disaster management, such as campaigns, discussions and training
- Approximately, 20 percent of villages had early warning systems.
- About 20 percent of villages had cyclone shelters.

Reconstruction

- Around 69 percent of villages reported that it took more than 15 days to reconstruct the houses.
- Most of the villages reported that road reconstruction took more than 15 days.

Future Perspective

- Most of the villages were aware of EWS and planned to install new systems.
- Cyclone shelters were used as COVID-19 shelters during the pandemic.
- Villages had clear and consistent communication about COVID-19.

Annexure 5: Institutional Survey (Profile and Respondent Overview)

Jagatsinghpur **Khordha**

- >83 percent of institutions have well-maintained wires/cable.
- >73 percent of institutions have functional distribution transformers close by as a source of electricity.
- 60 percent of institutions depend on the Water Board for water supply.
- All institutions are under the jurisdiction of CESU (area with high exposure).

Institution Mix by Ownership

- Public: 46.67%
- Private: 53.33%

Institution Mix by Sector

- Agriculture: 10%
- Commerce: 10%
- Housing: 6.67%
- Health: 3.33%
- Industry: 36.67%
- Railway: 6.67%
- Telecommunication: 3.33%
- Tourism: 10%

Pre-Cyclone Fani Scenario

- About 90 percent of institutes had electricity available through solar panels, wind, renewable energy and diesel generator sets as power outage alternatives.
- No steps had been taken by the Department of Energy personnel prior to Cyclone Fani to limit the disaster impact.
- Reportedly, 90 percent of institutions did not witness any electricity outage warnings.

During Cyclone Fani Scenario

- No accidents caused by electrocution
- About 68 percent of institutions did not have access to electricity for more than 10 days.
- Around 90 percent of villages experienced power fluctuations after electricity restoration.
- About 30 percent of institutes suffered appliance damage due to electricity fluctuations.
- Around 63 percent of institutes were not operational as there was no electricity supply for more than a week.
- About 95 percent of institutions reported damages to nearby electricity poles during Cyclone Fani, of which 63 percent reported severe damages.
- Around 31 percent of institutions reported adverse impact on transformers in their areas.
- Almost all institutes reported damages to service and transmission wires and cables.

Post- Cyclone Fani Scenario

- There was no relief from electricity service providers in terms of the following:
  - a) Waiver of fixed charges of electricity for the duration of non-availability of power supply due to Cyclone Fani.
  - b) Granting instalments on pending dues.
  - c) Reduced electricity tariffs after Cyclone Fani.

- Power providers' response to outage complaints during the disaster was unacceptable, with no prior information from suppliers regarding likely power cuts across identified feeders/power lines during the cyclone.

Annexure 6: Institutional Survey (Impact Analysis)

Sector Impacted	Stakeholders	Direct Impact	Indirect Impact
Power	OPTCL, TPCODL, WESCO, SOUTHCO, NESCO	» Power supply disruptions/ fluctuations across impacted areas » Revenue loss and deferred revenues for previous sales » Damage to critical power infrastructure components » Electrocution due to fallen low-tension (LT) lines and poles » Damage to communication systems such as SCADA, GIS and AMI, among others » Contractual loss » Losses incurred in running secondary power	» Damage to electrical appliances due to voltage fluctuation » Water shortage across villages » Agricultural loss due to irrigation-related issues » Closure of educational institutions » Production loss
Tourism	OTDC Jagannath Temple, Puri	» Revenue loss » Damaged heritage sites, monuments and buildings » Losses incurred in running secondary power » Operational interruptions due to power outages	» Decrease in footfalls at temples » Losses faced by small and roadside vendors

Sector Impacted	Stakeholders	Direct Impact	Indirect Impact
Transport	OSRTC East Coast Railways	» Infrastructure damage » Operations impact associated losses » Losses incurred in running secondary power » Reduced cash flows	» Losses incurred due to delays in bus and train timings » Losses incurred due to a decrease in the number of travelling passengers » Losses incurred due to disrupted operations
Industry	MSME Department (GoO) Indian Chambers of Commerce-Odisha	» Production loss » Contractual loss » Closure of cottage industries » Losses due to power outages	» Labour shortfall » Losses incurred due to disruption in logistics and supply chain management
Telecom	BSNL/AIRTEL Jio	» Power outage losses » Associated infrastructure damage » Other IT hardware damage Losses incurred while » running secondary power Revenue losses due to » network unavailability	» Public property damage » Impact on establishments » Tower damage affecting LT power lines

Annexure 7: Institutional Survey (Multi-Tier Analysis)

Hazard Identification

- All institutions receive first information about oncoming disasters through print/digital media and radio.
- Institutions had previously been hit by cyclones, and hence, remain vulnerable to such events.
- About 90 percent of the institutions had experienced more than three hazards in the past five years, making them highly vulnerable.
- Among their experiences, Cyclone Fani had been the most severe natural disaster.

Hazard Impact

- Around 63 percent of institutions experienced damages to infrastructure and building structures, of which 42 percent was severely damaged.
- About 31 percent of institutions experienced a huge impact on business continuity whereas 29 percent were moderately impacted.
- Around 3000 fishermen were injured.
- About 57 percent of institutes were not operational for more than a week.
- Most institutions had damaged water supplies.
- Water logging was reported across vicinities of establishments due to overflooding.
- Bhubaneshwar Railways suffered losses amounting to INR 12 crores.
- Most institutes reported revenue losses and deferred cash flows.
- All institutions reported disruptions in services to their end consumers.

Disaster Preparedness

- Before Cyclone Fani, most institutions were not aware of state-level disaster management plans. During Cyclone Fani, institutes did not have an internal disaster management plan in place.
- Most institutes reported having disaster management emergency kits and equipment.
- Around 63 percent of institutes were provided pre-disaster information and announcements via disaster management departments.
- Only a few (36%) institutes organized mock drills to enhance disaster preparedness prior to Fani and Amphan.

Response and Relief

- Institutions were informed about the hazard's status through televised programmes, ground-based public address systems and radios, among others.
- No support was provided to the institutions in terms of loans, grants, or interest moratorium periods.
- About 60 percent of institutions reported that the relief activities by SDMA in the aftermath of the disaster were inadequate.

Annexure 8: Stakeholder Survey (Multi-Tier Analysis)

Stakeholder	Survey Snapshot
State Power Infrastructure Stakeholders	• Limited awareness of established disaster management plans among employees, no updates to the disaster management plan in the aftermath of Cyclone Fani and an absence of disaster-specific SOPs. • Non-availability of block- and village-level power infrastructure details. • Non-availability of a GIS map of the critical power infrastructure to assess the risks from various hazards. • Non-availability of a digital repository of power infrastructure details at central/field level, limiting the utility employees' capacity to assess post-disaster damages or plan for new power infrastructure in a timely manner. • No collaborations by DISCOMs with design and research institutions before Fani. • Absence of resilience factor in project planning across distribution companies. • Limited availability of funds to undertake infrastructure upgradation projects such as burying LT networks, in-house conversions of outdoor substations and improvements to research designs.
Disaster Management Authorities	• Non-availability of a digital repository of infrastructure damage and state department-specific response and reconstruction measures, limiting the state's capacity to prepare and assess risks from future hazards.
Regulators	• Absence of a regulatory framework and policies mandating the institutionalization of disaster management practices for stakeholders across Odisha's power infrastructure ecosystem.
National Nodal Power Entities	• Non-introduction of policies and projects to enhance power infrastructure resilience.

Stakeholder	Survey Snapshot
National Nodal Power Entities	• The Ministry of Power designated the National Load Dispatch Centre (NLDC) as the Central Control Room to deal with crises and disasters in the power sector. • There is an urgent need for design improvements across critical structural components such as distribution side poles and power lines.
State Government/Finance Departments	• There is a need for collaboration across the Asia-Pacific region to bring structural and non-structural improvements to power infrastructure. Institutional focus must be on design and research improvements across the power sector.

Annexure 9: Case Studies-Developing Infrastructure Resilience

DRC (Disaster Response Centre)

Implementing Entity: OPTCL

Estimated Cost: INR 151.33 Crore

Year: 2016 (3 Years; in the aftermath of Cyclone "Phailin")

Objective: Facilitate quick restoration of power supply during natural disasters.

Key features: Located at Chandaka and Meramundali

- The disaster resilient power system scheme attempts to develop transmission infrastructure in disaster-prone areas in order to ensure sustainable power supply during calamities.
- It involves the development of a transmission system, located within a distance of 60 km from the coast.
- The scope of work includes the retrofitting and strengthening of foundations, and the installation of interposing angle towers across long stretches.

Radial to Ring Conversion Project (RRCP)

Implementing Entity: OPTCL

Estimated Cost: INR 1,450 Crore

Year: 2016 (3 Years; in the aftermath of Cyclone "Phailin")

Objective: Facilitate quick restoration of power supply during natural disasters.

Key features:

- It aims to identify radial grids and convert them into a ring system that helps eliminate blackouts during natural calamities.
- Underground cabling is being used for ring connectivity in Cuttack and Bhubaneswar

Aapada Mitra Scheme

Implementing Entity: OSDMA

Objective: The initiatives is taken for providing shelter to the community

Key features:

- To train able-bodied community volunteers in disaster response (flood relief and rescue) at the taluka/block level in each of the project districts. These trained volunteers will be called as "Aapda Mitra".
- To develop standardized training modules for the set of trainings under the scheme.
- To train the volunteers in life saving skills of disaster response, coordination and assistance, and protective equipment and emergency responder kit.
- To disseminate training and education tools developed under the project to a greater number of flood prone districts in subsequent phases of the scheme.

Odisha Power System Emergency Assistance Project (OPSEAP) - Distribution

Implementing Entity: OPTCL (ADB funded)

Year: 2014

Objective: It was planned to build a power supply distribution network resilient to the super cyclone of the wind speed of 350 kmph.

Key features:

- To design distribution network infrastructure adequate to take care of load growth of next 10 years and create the same for catering load growth of 5 years.
- To elevate the outdoor infrastructure above the defined flood levels.
- To build up 33 kV ring main system in Berhampur Town and special measures to improve supply reliability through dedicated links to important installations like Hospitals, Water Supply, Railways etc.

Building Homes to Withstand Cyclones in Odisha

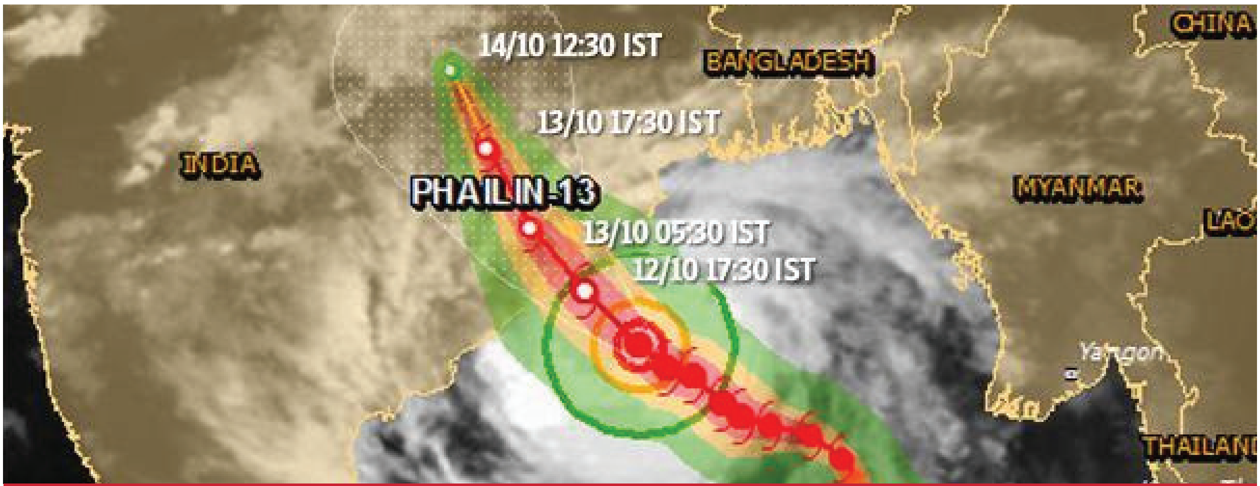
Implementing Entity: Caritas India with the support of United way Bengaluru (UWB)

Year: 2020

Objective: The initiatives is taken for providing shelter to the underprivileged communities across India those who are afffected such cyclone, flood, and other disasters.

Key features:

- These cyclone resistance houses are designed to face wind speed up to 200/hr
- The structure is designed with various disaster components like column foundation, plinth and grade beam, connectivity of all the column and beam.
- The design of the permanent disaster-resilient house serve the multi-hazard resistance and equipped with anchorage, bracings, connections, detailing's etc.



Annexure 10: District and Village Selection Framework

Figure A10.1: Districts' vulnerability to natural hazards

Districts	F	C	L	D	E	I
Puri	●	●		●	●	●
Cuttack	●	●			●	
Ganjam	●		●	●		
Jagatsighpur	●	●			●	●
Jaipur	●	●		●	●	
Bhadrak	●	●		●		
Balasore	●	●		●		
Kendra Para	●	●			●	
Khordah		●			●	
Dhenkanal		●				
Mayurbhanj			●			
Nayagarh					●	

F-Flood
C-Cyclone
L-Lightening
D-Drowning
E-Earthquake
I-CVI

Figure A10.2: Overall impact of Cyclone Fani: relative scores

Districts	S1	S2	S3	S4	S5	S
Puri	19	4	7	4	40	74
Cuttack	30	5	8	3	6	53
Jagatsighpur	24	4	6	4	9	48
Ganjam	19	8	10	10	-	48
Jaipur	21	4	7	2	3	37
Kendra Para	15	3	6	2	3	29
Balasore	11	5	9	3	-	28
Mayurbhanj	2	10	4	2	4	22
Bhadrak	10	3	3	3	-	19
Nayagarh	3	3	4	4	-	14
Kordha	5	3	1	2	-	11
Dhenkanal	1	3	2	3	-	10
Keonjhar	0	3	1	1	-	5
Angul	0	2	0	-	-	2

S1-Population Impacted
S2-Blocks Impacted
S3-Villages Impacted
S4-ULBs Impacted
S5-Human Casualty

Figure A10.3: Village selection framework-identification of villages affected by heavy winds during Cyclone Fani

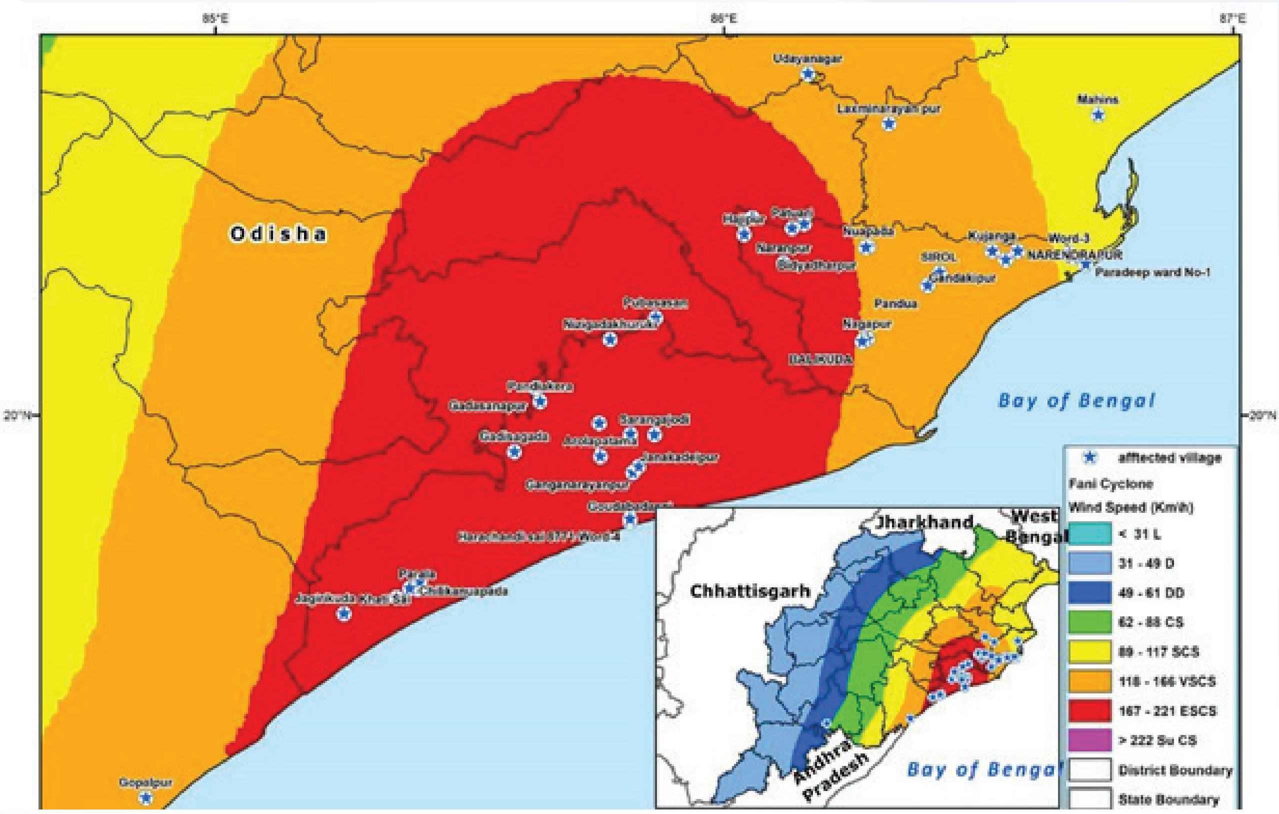
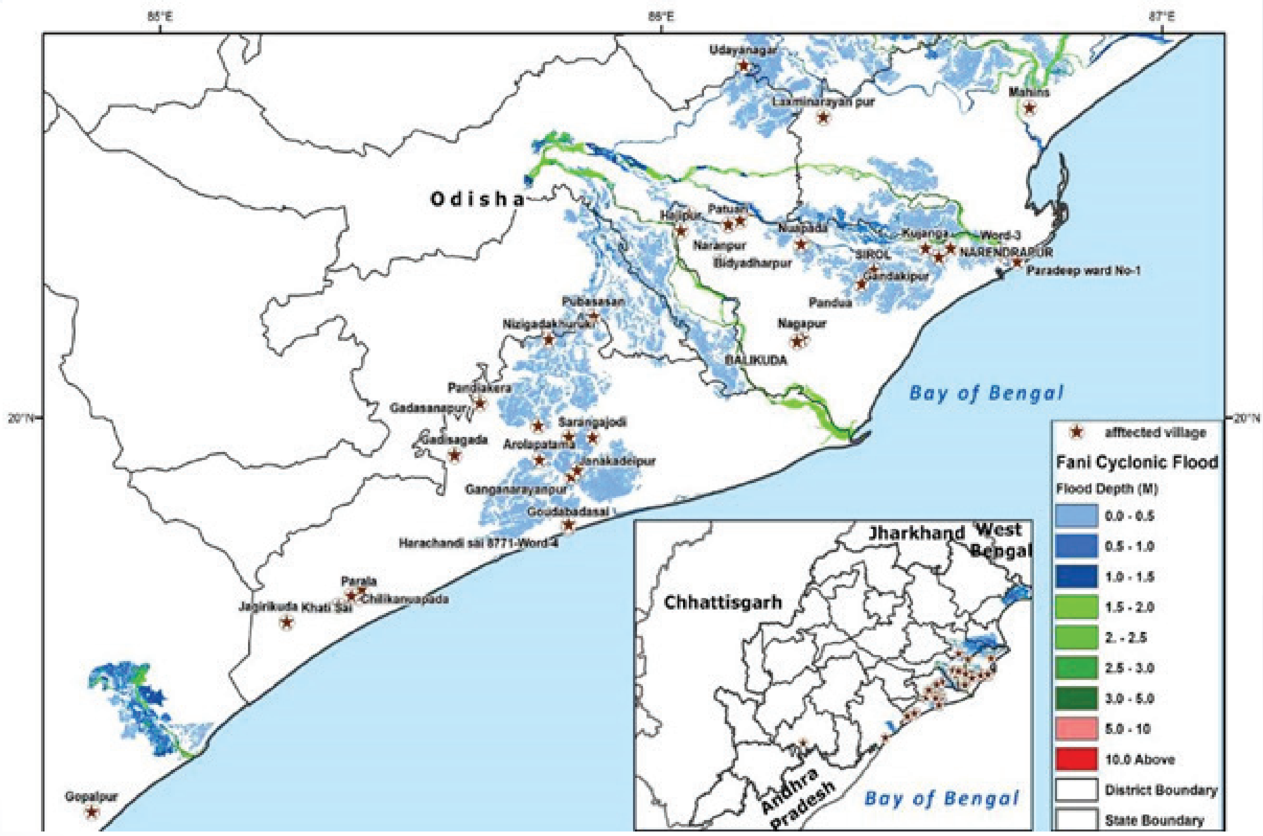


Figure A10.4: Village selection framework-identification of villages affected by floods during Cyclone Fani



Annexure 11: Expert Panel Consultations for the Study

Organization	Designation
Department of Energy	Principal Secretary
OPTCL	DGM – Electrical
WESCO	DGM – Electrical
NESCO	Administrative Officer
TPCODL	CEO
GRIDCO	Chairman
GRIDCO	Managing Director
GRIDCO	Director, Finance
OSDMA	Executive Director
Department of Industries	Principal Secretary, Department of Industries
Department of Revenue and Disaster Management	Principal Secretary, Revenue and Disaster Management
Odisha State Finance Department	Principal Secretary, State Finance department
Telecom	CGM, BSNL Odisha Circle
Department of Industries	Joint Secretary

Annexure 12: Sample Survey Questionnaire

Survey Questionnaire for DISCOMs

Name:

Designation: Department

Place of Posting:

Questions **Responses**

Disaster Impact to Power, People, Other Infra, Costs and Damage

1. Employee fatalities, if any, during Fani? Count
2. Loss of revenue due to damages to EHV lines from cyclone Fani and comparison with other past disasters? (In INR Cr)
3. What is the total number of electrocution incidents or accidents related to EHV lines due to Cyclone Fani's impact?
4. What is the financial implication of electrocution instances during Cyclone Fani's impact period? (In INR, Cr)
5. Was there any damage to assets during Cyclone Fani? (In INR, Cr)
6. Was there any abnormal voltage or frequency increase observed during Cyclone Fani?
7. Was there ckt km of EHV lines damaged during Cyclone Fani?
8. How many power transformers were damaged during Cyclone Fani? (In nos.)
9. Was your IT hardware impacted during Cyclone Fani?
10. Was your IT software impacted during Cyclone Fani?
11. Was the communication system with respect to SCADA, AMI, GIS, etc., impacted in any manner during Cyclone Fani? Elaborate.

Disaster Management Policy and Institutional Setup

12. Which year was the BCP/DM plan established?
13. Have there been any revisions/updates to the BCP/DM plan considering the evolving disaster scenarios?
14. Have there been any trial/mock drills to check the efficacy of the DM plan/BCP?
15. Have you revised the DM plans/BCPs post-Cyclone Fani?
16. Were the DM plans/BCPs activated during Cyclone Fani? If yes, what is the approach and methodology for implementation?

17. Are there nodal team/response groups for pre-, during- and post-disaster scenarios, as per the DM plans/BCPs?
18. Have your employees been made aware of established DM plans/BCPs?
19. Is the concept of infrastructure resilience embedded in the DM plan/BCP?
20. Have you documented the learnings from Cyclone Fani and past disasters? If yes, is it digital or manual? Elaborate.

Disaster Preparedness (Overall Including Financials)

21. Based on the learnings from past disasters, were any changes in practices carried out that benefited during the Cyclone Fani phase? If yes, elaborate.
22. Was there a preventive maintenance schedule in place to strengthen the vulnerable network? If yes, please elaborate.
23. Were any infrastructure schemes planned for power transmission resilience enhancement, in general?
24. Are you familiar with the vulnerable areas for power transmission infrastructure based on past learning?
25. Were any infrastructure schemes planned for power transmission resilience enhancement across vulnerable areas?
26. Did you seek scheme approval for resilience enhancement?
27. Did you carry out an internal damage assessment post-Cyclone Fani? If yes, what were the key findings and key learnings? What was the approach towards damage assessment?
28. What operational, financial and institutional measures were in place to ensure adequate operational continuity during- and post-disaster?
29. Do you provision the fund requirements for transmission infrastructure resilience in your early ARR requirements? If yes, are these allowed by the regulator?
30. Have you received state or central funds for the transmission infrastructure resilience enhancement scheme?
31. Have you sought any state funds for the infrastructure resilience enhancement scheme?
32. Are field offices aware of DM plan/BCP and corresponding SoPs well in advance?
33. Are there SoPs in place for business continuity?
34. Are there any contingency contracts with material suppliers and other service providers for restoration during disaster activities?
35. Do you have any insurance mechanisms in place as a relief measure from disasters?

36. Did you carry out any specific intervention to enhance transmission infrastructure resilience in vulnerable or other areas under your jurisdiction?

37. Were you in coordination with the state DM/relief team regarding power transmission infra-restoration requirements?

38. What were the IT safeguards in place for business continuity?

39. What was the reporting mechanism in place for reporting damage to critical infrastructure in the affected areas during Cyclone Fani?

Disaster-related Information

40. Was information related to the cyclone received within time from the Met Department or any other agency? What was the agency's name?

41. Based on your understanding of impacted infrastructure, was the communicated cyclone path per actual prediction?

42. Were the communicated cyclone impact areas informed?

Response During Disaster

43. Was the DM Plan/BCP put into action during a disaster? How?

44. Brief details of challenges faced in implementing the DM plan, if any?

45. Were there any response teams at the field level to address power transmission related issues? If yes, were they able to perform their activities efficiently/smoothly?

46. What challenges did the power restoration response teams face during the restoration period?

47. Was any special task force formed to provide real-time information on load flow from SLDC?

48. Were all the metre data communication devices working during Cyclone Fani?

49. Were the contractors equipped with adequate tools, tackle, hydras and boom vans, among others? Were there any challenges?

Restoration and Reconstruction

50. Could you assess the overall damage to power transmission infrastructure under your jurisdiction? What was the approach? How much time did it take for you to do so?

51. In how many days could you restart the reconstruction work in a planned manner?

52. Was there any improved electrical equipment/material used during the reconstruction phase? If yes, please elaborate.

53. Was any improved electrical equipment/material used during the immediate restoration phase? If yes, please elaborate.

54. How many personnel were engaged in immediate restoration activities?

55. Where the pre-during and post-disaster SoPs in place during Cyclone Fani?

56. Do you have work contracts specific to post-disaster restoration works? If yes, salient features, please?

57. What was the nature of funds in use for post-disaster restoration activities such as state/central government loans, grants, domestic banks, NBFCs and othe international multilateral agencies?

58. Were funds made available to the field in time to deal with restoration work after Cyclone Fani? (Percentage of allotted funds)

59. What were the challenges regarding the availability of critical materials such as electrical poles, power lines and transformers? Elaborate, if any.

60. During the immediate restoration activities, were there any delays in transporting critical power infrastructure, such as electrical poles, power lines and transformers?

Preparedness-Technology

61. Were UAS or drones used to monitor remote areas during a disaster? Where are they operational during Cyclone Fani?

62. Do you have a disaster alert/warning prediction system across control rooms, field offices, or command centres that may be linked to the state's Met. Dept. or OSDMA? Please elaborate.

63. What was the mode of communication used to update end consumers (institutional, community and other state stakeholders) on power supply and likely outages?

64. What was the mode of communication in place for updating and warning the field offices on the likely or anticipated disasters and Fani itself?

65. Are all primary S/S connected with SCADA? (as a percentage of overall S/S)

66. Were any emergency restoration tower systems available to quickly restoration of damaged EHV lines? Brief description

67. Were any communication gaps felt with distribution wings during Fani? Brief description

Preparedness-Capacity Building and Training

68. Is there a training framework for various organizational-level employees on an established BCP/DM plan? If yes, what was the training schedule? Is the trainer internal or external?

69. Were several training sessions exclusively organized for field-level employees post-Fani?

70. Were some training sessions exclusively organized for internal disaster response employees post-Fani?

71. Have there been any assessments to gauge the awareness level among employees on the DM plan/BCP?

72. Have there been any educational tours for employees to other disaster-affected states/countries regarding disaster management/mitigation advancements? If yes, please share details of the programme undertaken.

73. Was any centralized control room formed to inform people about possible hazards or to minimize electrocution incidents?

74. Did you provide any training to your technicians on installing an emergency restoration tower in case of emergencies?

75. Were some training sessions organized for field officials to deal with disaster?

76. Do you arrange MDP programmes for your employees across India's best disaster management institutes? What is the number of people in attendance?

Annexure 13: Advisories Issued to Power Sector Stakeholders by the Coalition for Disaster-Resilient Infrastructure

Preparing for the Cyclone Season

Advisory to Power Sector Stakeholders

Enhancing the resilience of the power sector not only involves strengthening its ability to anticipate and absorb shocks but also improving its capacity to recover from the effects of a hazardous event more quickly and efficiently.[35]

In 2019, Cyclone Fani, with gusting winds at 205 km/h, caused extensive damage to Odisha's power infrastructure, approximately INR 8392 crore (US$ 1.2 billion).[36] The power sector sustained the maximum damage and losses compared to all the socio-economic infrastructure across various sectors in the state.

[35]Wang Xiaoping, Brown Ray, Prudent-Richard Guillaume, O'Mara Katrina. 2016. Enhancing Power Sector Resilience: Emerging Practices to Manage Weather and Geological Risks. Washington, D.C.: World Bank Group. Details available at http://documents.worldbank.org/curated/en/469681490855955624/Enhancing-power-sector-resilience-emerging-practices-to-manage-weather-and-geological-risks

[36]United Nations, ADB, World Bank. 2019. The Cyclone Fani - Damage, Loss, and Needs Assessment (DLNA), Odisha State. Details available at https://recovery.preventionweb.net/media/74593/download?startDownload=20240927

Since then, CDRI has been working with the state's power stakeholders to learn from the impact of the cyclone and enhance the resilience of the state's power infrastructure to disasters, especially those caused by extreme climatic events like cyclones. So far, CDRI has identified a few steps that could be taken by stakeholders in the power sector around the world. With the aim of minimizing the adverse impact on power systems and enabling quicker restoration and recovery activities, here are some suggested measures.

Immediate pre-impact activities

- Create a webpage/section on DISCOM websites that is conspicuously visible, providing regular updates regarding the names of the nodal officers across localities and updates on power outages, restoration and timelines for consumers.

- Create a central war room to monitor, respond and coordinate grid supply status and damage to infrastructure. Seek regular updates on the cyclone's status from the Meteorological Department and Disaster Management Agencies.

- Form core teams across generation, transmission and distribution utilities in the region to coordinate regarding the following:
  (i) material procurement and management, (ii) manpower arrangement and deployment, (iii) logistics/transportation, lodging and boarding, and food, (iv) collection of field information and MIS preparation/reporting, (v) coordination with field offices through messengers.

- Contact all hospitals and nursing homes other than medical establishments (especially hospitals catering to COVID-19 and other critical patients in ICUs and oxygen wards), banks, and government departments of disaster management and relief in likely impact areas to assess the availability of back-up power supply such as diesel generators (with sufficient fuel) and check the status of secondary supply (if any) for these establishments. Inform all critical installations such as airports, ports, railways and major industries of likely power disruptions to allow them to take measures for back-up power/safe handling of units.

- Constitute an emergency procurement committee at an appropriate level to oversee immediate procurement requirements, rate negotiations with local vendors and coordinate with vendors in other nearby regions.

- Take stock of and create an inventory list of critical materials such as power/distribution transformers, low-tension and high-tension poles, conductors, ABC cables, substations, emergency restoration towers, cross-arms, v-cross arms, GI pins, insulators and other components that are susceptible to damage due to high-speed winds or floods or may require post-damage recovery.

- Accommodate the available stock of agencies (along with their contractual human resources) across the departments involved in capital projects, operations and maintenance activities. All such agencies may be immediately contracted for restoration at agreed rates.

- In advance, contact all certified and/or technically qualified contractors to provide skilled human resource assistance during reconstruction.

- Set financial limits for field engineers/staff regarding immediate local procurement, with guidelines specifying the material that can be procured as per approved rate lists.

- Ensure power transmission and distribution utilities are checking for equipment availability regarding hydra, pole master, tractors, trucks and buses, emergency lights, marsh boats and DG sets (with sufficient fuel) that may be vital for restoration activities. These should be strategically pre-positioned across the areas likely to be impacted to enable prompt restoration. The emergency procurement team should be ready to contact suppliers immediately for rent/lease/purchase of such equipment, along with their operators and other human resources, in case of their unavailability. Additionally, utilities in neighbouring regions may also be contacted to provide such equipment on loan, if needed.

- State power departments/utilities may contact their counterparts in neighbouring states to make prior arrangements regarding skilled human resources and material support for restoration activities, as and when required.

- Request employees to reconsider approved leaves, considering the support required from all qualified human resources.

- Adhere to Environment, Health and Safety (EHS) protocols across offices, war rooms and field staff (required for recovery and reconstruction).

- Deploy local teams to identify and clear any trees and vegetation that may damage power lines or other power infrastructure.

» Take adequate safety measures to protect solar power panels from high winds and storm surges across generating stations.

Activities amid the cyclone impact period

» Undertake the following activities in a coordinated manner to ensure grid security:

(1) Temporarily switch off 33 kV feeder lines experiencing very high wind speeds.
(2) Immediately shut down 11 or 33 feeder lines that report damage to over-head conductor with damaged or uprooted poles.
(3) Coordinate with the Regional Load Dispatch Centres (RLDCs) and take corrective measures to ensure the overall continuity of the grid.

» Share regular power outage updates on the existing company website and consider sending consumers messages and emails to their registered contact information.

» The central war room must contact the Meteorological Department for updates regarding the cyclone's evolving path.

Near-term restoration and reconstruction activities

» Adopt a two-phased approach to assess damage, the first being a quick rough assessment by personnel on two wheelers or on foot. Determine the damage inflicted upon power supply across critical institutions like government or private hospitals, water supply, telecommunication, government offices, railway stations and airports. This will enable effective and timely communication with emergency field teams. The second phase will involve a detailed assessment to understand the impact of extensive reconstruction.

» If a larger section of the transmission and distribution system requires a black start after the passage of the cyclone, sub-sections must be switched in coordination with the RLDC to ensure minimum disturbance to the power grid.

» The local government may receive information regarding estimated damage and immediate fund requirements for restoration and reconstruction activities.

- Mobilization advances may be provided to contractors and agencies involved in restoration and reconstruction activities to cover expenses and pay the workers involved.

- The government or power utilities might want to consider announcing incentives for early completion of restoration work to the contractors involved.

- Safety officers must be designated across adversely impacted areas to prevent untoward incidents while conducting response and restoration tasks. These tasks include addressing issues like back feed current and broken conductors when responding to flooded areas. Safety officers must also ensure that the entire workforce follows EHS-appropriate guidelines.

- If bulky equipment, such as power transformers in switch yards, is severely damaged, the concerned power infrastructure stakeholder should ensure that a quick replacement mechanism is in place. The utility may seek government support for managing logistics (in case the equipment is at a distance or in a remote area).

- An ultra-high-definition surveillance camera mounted on drones (UAVs) with GIS-based transmission and distribution maps (if available) can be used for an aerial survey to assist in quickly assessing damage in highly impacted and hard-to-reach areas.

- Local government administration and police may be contacted in advance for help to avoid any law-and-order situation during restoration and reconstruction activities.

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This advisory is based on CDRI's work with the State of Odisha, drawing on lessons from the state's experience of dealing with the impact of Cyclone Fani on its power infrastructure in 2019.

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