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Enhancing the Utility System Resiliency

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SUSTAINABLE TRANSFORMATION OF UTILITIES

THE THEME

The theme of the World Utility Summit, (WUS) is “Sustainable Transformation of Utilities”.

This summit would bring in thought leaders across the globe to deliberate the preparedness of utilities to deal with the transformational changes. Regulators, technology providers, consultants, government bodies and utility leaders are expected to share their views on the various challenging and exciting scenarios and help shape the roadmap of the future utilities.

SUMMIT TRACKS:

Accelerating Digital Journey of Energy Ecosystem

Utilities get their revenues primarily via billing the customers for their demand and energy usage. New energy ecosystem, with multiple options for consumers to meet their electricity demand, will pose stiff competition to the utilities. Earlier for paying electricity bills a long que has to be made but in today's era the process has been digitized. With the use of smart meters, every process is digitized and simple. The questions arise in what manner digitization of energy ecosystem will affect the consumers?

Best Practices in Asset Management

Proper asset management allows company to effectively provide their service to the nation. Any breakdown in this process brings the potential for catastrophic failure in the nation infrastructure. Proper asset management allows you to:

- Enhance the life of assets through proper maintenance
- Allows you to respond efficient during emergency situation
- Reduce operating cost in long term.

The four main pillar of the asset management are:

- Evaluate your system's asset
- Assess your current service level
- Identify your most critical component
- Map out your life cycle cost
- Develop maintenance plan

Enhancing the Utility System Resiliency

In this environment, the utilities, Government and others stakeholders needs to take longer and deeper look at building resilience to limit and mitigate the risk to customers. Protecting them from risk that threaten life, property and economic activities that can be costly. We would like to suggest important pillars in the effort to improve our Nations grid resilience.

- Smartening the Grid
- Hardening the Grid
- Distributed Generation
- Building resilience on demand

Distribution Utilities of Future: Advanced Technologies for Business Transformation

The Indian power sector is evolving at a fast pace and has undergone some major transformations in recent past aimed at improving grid efficiency, security, stability, and consumer experience. However, the distribution utilities remain the weakest link in power sector value chain. The deployment of advanced technologies such as smart-grids can reduce pilferage, enhance consumer participation, and realize more revenues through losses reduction, lower energy costs, and eliminate manual intervention. Further, the combination of advanced technologies, innovative market models and consumer engagement strategies can support solutions like grid interactive buildings and enable consumers to support the distribution utilities in managing the demand supply balance. Together, such technologies and solutions have the potential to transform the distribution utilities and accelerate the use of clean energy resources in power grids.

Sustainable Practices towards Net Zero Utilities

In current scenario, Energy and Utilities executives are working towards sustainable practices. Almost half of the energy and utilities respondents have committed to a net zero goal. The major driving factors for sustainable utilities are upcoming government policies favorable to consumers and industry, increasing consumer and shareholder demand, and Decreasing cost of renewable energy. The important question arises how the Utilities are building a sustainable future.

New Energies (Common track with eTECHnxt)

The Indian renewable energy sector is the fourth most attractive renewable energy market in the world. As of May 2022, India's installed renewable energy capacity stood at 159.94 GW which is 39.70 % of the overall installed power capacity. People everywhere are looking for new energy ideas to help them make energy smart decisions for the future. We believe in renewable Energy and changing the attitude and practices about the way people generate and use energy. Central to this is the discovery and development of alternative energy sources. This track will cover the latest developments in technologies, novel business ideas, grid dynamics, learnings from pilot demonstrations and working considerations associated with these technologies. The topic will emphasis on Green Hydrogen, Electrification of Transportation, Nuclear & Biomass.

MESSAGE FROM KNOWLEDGE PARTNER

Amit Prothi
Director General,
Coalition for Disaster Resilient Infrastructure (CDRI), India

On behalf of the Coalition for Disaster Resilient Infrastructure (CDRI), I wish World Utility Summit 2023 all the success.

The six topics discussed in WUS-2023 include Accelerating Digital Journey of Energy Ecosystem, Best Practices in Asset Management, Enhancing the Utility System Resiliency, Distribution Utilities of future: Advance technologies for business transformation, Sustainable Practice towards Net Zero and New Energies that will be discussed in WUS-2023 are very relevant to all stakeholders with the changing business models that continue to focus on clean energy.

There is an urgent need to understand and manage risks in critical infrastructure. When infrastructure fails to perform its services, especially in times of crisis such as earthquakes, floods or cyclones, hurricanes, a natural event can turn into a major disaster affecting lives and livelihoods. A comprehensive and integrated approach that includes regular risk assessments, resilient infrastructure, diversification of energy sources, and implementation of smart grid technologies can help power utilities effectively manage the impacts of disasters and climate change. Additionally, building partnerships with government agencies, communities and other stakeholders, and investing in research and development can help utilities stay ahead of emerging risks and develop innovative solutions to improve their resilience.

By taking these steps, utilities can ensure they are well-positioned to continue and provide reliable, sustainable energy to the communities they serve. Therefore, it is crucial to improve and set aligned outcomes for regulators, asset owners, grid operators and the community, based on the principles of resilience, across sectors and jurisdictions. Additionally, governments and the private sector should develop frameworks, tools and incentives that encourage the adoption of resilience in infrastructure investments.

This white paper touches on the topic **"Enhancing the Utility System Resiliency".** Even though some topics are well discussed in various forums, the efforts have been made to bring in the institutional framework to design a resilient utility grid. Institutional capabilities are important throughout the sector in developing a resilient grid. The design standards of the infrastructure assets, the ongoing maintenance of assets, and the organized response during hazard incidents have major implications for the performance of the electricity grid.

We would like to wish the participants knowledge sharing in critical areas about the subjects among a large audience of power utilities, manufacturers, researchers, academia, and, most importantly, end-users.

I want to express my appreciation to KPMG, PRDC, PWC, and TARU for their commitments to this document through their various engagements with CDRI.

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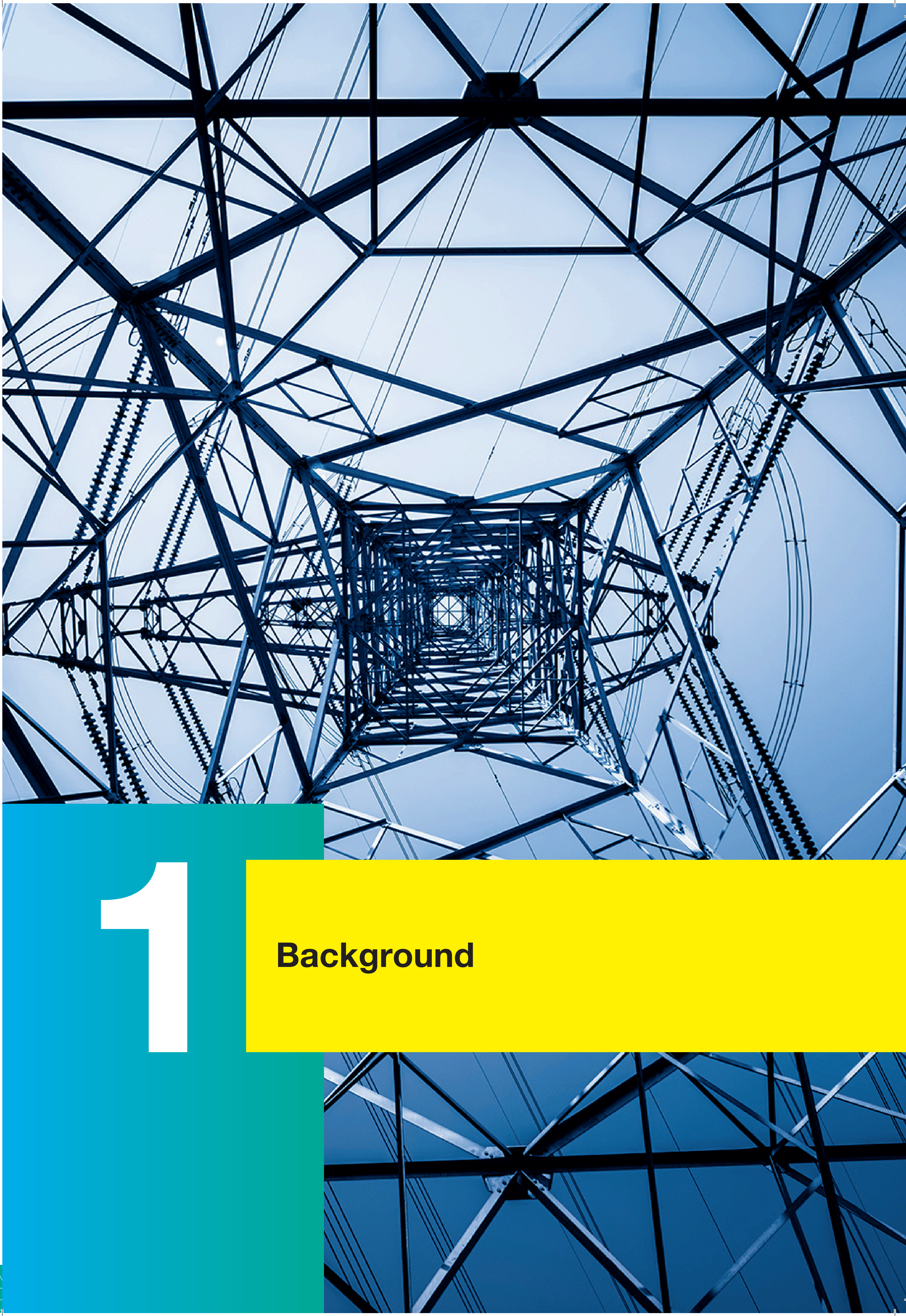


1 Background

The extreme weather events like droughts, heat waves, heavy rains, cyclonic storms, etc. are the severe effects of global climate change in the last 30 years. The frequency and intensity of cyclonic wind have increased over the years causing large scale damage to T&D (Transmission and Distribution) infrastructures of coastal states. The impacts of the cyclone brought into focus the need for disaster and climate resilient power infrastructure systems not only in India but in the world as a whole. This represents another opportunity highlighting the imperative to build better and more resilient power infrastructure.

In a world that relies increasingly on electricity services, building the resilience of power systems is critical to providing reliable and sustainable services, energy security, economic well-being, and quality of life. 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”. While there are existing international best practices for risk reduction, developing countries will have to adapt the solutions to its own situation and context. The overall aim of this white paper is to enable the enhancement of the resilience of Power infrastructure to disasters, especially those emanating from extreme climatic events, through raising awareness and enhancing understanding about managing risks among power sector stakeholders, and enhancing their capacity to take adaptive actions to mitigate these risks and cope with the impacts of future disasters.

The main task of risk mapping and improvement of infrastructure is to assess the extent of risk and the vulnerabilities of the power sector infrastructure. Detailed approach and of risk mapping are described as follows:

1.1 Risk mapping and improvement of power Infrastructure

1.1.1 Risk Identification and Estimation

Risk identification and estimation is an important milestone in risk mapping and improvement of power infrastructure. The major sub tasks under this are -

- **Baseline Diagnosis** – identification of key natural hazards in the specific geographical area; data collection; current situation analysis and assessment of steps taken by the government for climate change
- **Multi–Hazard Risk and Vulnerability Mapping and Assessment** – Assessment of hazard intensities across the geographical area; Preparing of Maps (First, Second and Third order risks)
- **Exposure Analysis** and Future Exposure Projection of Multi Hazards
- **Asset Prioritization Assessment** – current and planned future power infrastructure components
- **Gap Identification** for data/information to build power sector resilience and recommendations for better risk identification
- **Recommendations** on better data management for increased risk identification

Outcomes:

- Multi-Hazard Risk Maps for power infrastructure
- Risk Zonation for power sector
- Risk Identification Plan
- Asset Management and Allocation Plan

1.1.2 Codes, Standards, Design and Regulation

Codes, standards, design and regulation play an important role in designing the robust utility infrastructure. The major tasks under this exercise are -

- Comparative assessment of national & state level designs, codes, standards and identification of deviations
- Best practices assessment of implemented within the Power sector
- Gap assessment of design and implementation within the Power sector
- Component wise technical assessment and failure analysis
- International benchmarking assessment of sufficiency of design, codes and standards
- Recommendations on updating codes and standards for better disaster resilience

Outcomes:

- Comparative assessment of power sector norms/standards vis-a-vis global benchmarks

1.1.3 Technology and Innovation

Technology and innovation are vital to minimize the consequences of grid disturbances and avoid the major blackout and brownout in the grid following a disturbance or disaster. The major process under identification of the required technology and innovation are –

- Baseline assessment of current technologies, materials and design used for all the levels of power infrastructure
- Assessment of climate impacts on renewable energy infrastructure
- Benchmarking Analysis of global technologies used for risk mitigation in power infrastructure and gap identification
- Cost- benefit Analysis of possible technologies advancement through innovations
- Development of GIS based asset and multi hazard

Outcomes:

- Technology / Innovation need plan for power sector
- SOP of dashboard preparation

1.2 Institutional capacity and financing for resilience

A phased roadmap for improving resilience of power system in the areas of existing governance, finance and human resources with an aim to achieve a resilient power system that minimizes losses (to infrastructure and users) and recovers quickly from the impact of natural hazards. This part of the study should cover the following three aspects:

- Risk based governance and policy development
- Capacity mapping and development and knowledge management
- Financing resilience and adaptation

Some of the key services under each aspect are:

1.2.1 Risk based governance and policy development

- Process-mapping of the entire institutional landscape at national and state levels along with their hierarchy, responsibilities, reporting mechanisms, compliance obligations, funding mechanisms, and accountability mechanisms.
- Mapping of organizations, positions, methods, mechanisms, and processes through which natural hazard risk data is currently incorporated in governance, decision making, regulation and creation of power infrastructure.
- Documentation and review of policies and regulations that relate to risk reduction and along with a historical timeline of their evolution.
- Assessing the extent that policy and governance structures are enabling the inclusion of resilience in infrastructure development plans. These include laws, regulations, guidelines, and institutional frameworks for preparedness as well as response and recovery.
- Review of processes that allow the increase of systemic resilience, including regularly maintaining and updating asset inventories and maps of energy infrastructure, regularly assessing infrastructure vulnerability, and improving operations based on lessons learned from past events.
- Mapping of decision making, management, and coordination mechanisms for ensuring preparedness and early response to the impact of natural hazards.
- Mapping of the decision-making process followed in power sectors that allowed them to prepare for and respond to cyclones/other calamities. These will include decisions about operational and financial flexibility at different levels.
- Mapping of mechanisms in power sectors for institutional coordination and cooperation between stakeholders like utilities, governmental institutions, and municipalities.
- Recommendations on modification of existing policies to ensure resilience/graded resilience in upcoming infrastructure construction.
- Comparison with international best practice to devise recommendations on improving the above system to incorporate resilience considerations.

1.2.2 Capacity mapping and development and knowledge management

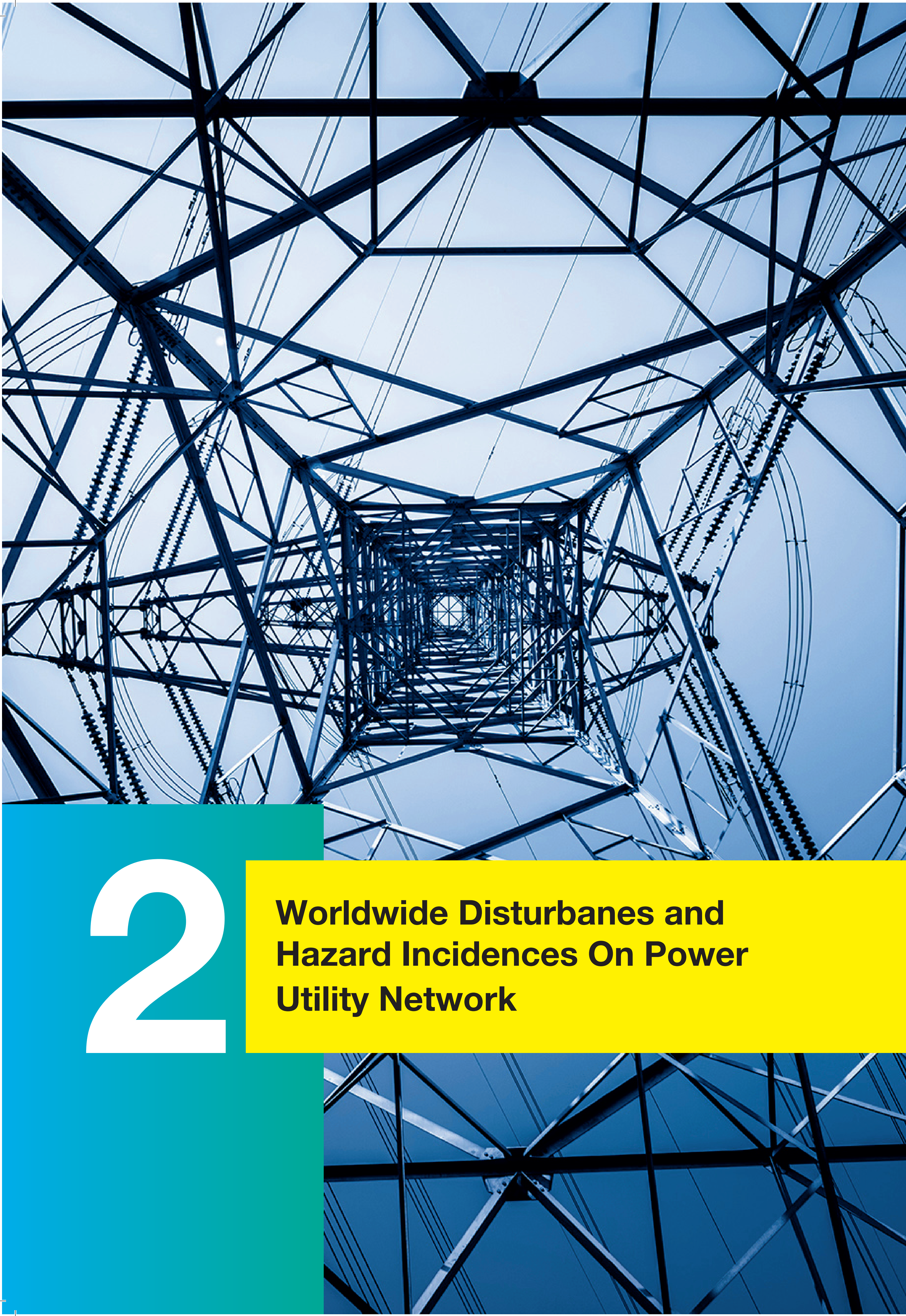
- Mapping of human resource availability at all levels. Normal pre-disaster and additional capacity required for post-disaster response and recovery. This includes mapping of sanctioned verses filled posts at all levels.
- Capacity mapping of departmental and contractual human resources at all levels on aspects of disaster risk management appropriate to each role. This includes the estimation and analysis of Knowledge, Skills and Attitudes at all levels.
- Documentation of training and capacity building initiatives taken up within the Dept. of Energy. This includes trainings on SOPs, Contingency plans, mock-drills, simulations, emergency management exercises etc.
- A Review of capacity building programs along with the sufficiency thereof. The study will look at how power sector plans and executes its capacity building programs by looking at processes for training needs assessment, frequency of trainings and outcome tracking.
- Recommend a system for power sector to monitor and develop capacities of various actors required to manage disaster risk.

- Assessment and review of the existing method and processes for knowledge management within the power sector.
- Identifying a corpus of documented knowledge – public domain documents, process manuals, organizational SOPs, training programs etc.
- Documentation and review of public outreach and IEC activities carried out by the Government to improve the resilience of electricity users.
- Recommend a process/system/method for power sector to manage knowledge efficiently and effectively within the system on all aspects of disaster management for the Power sector.

1.2.3 Financing preparedness, resilience, and adaptation

- Exposure assessment – Develop exposure dataset describing the power transmission and distribution assets for use in the modeling.
- Conduct Probabilistic Risk Analysis
- Assessment of “Base” Cyclone & Flood Risk - risk analysis of the ‘base’ exposure dataset of power transmission and distribution assets.
- Assessment of “Resilient” Cyclone & Flood Risk - counter-factual risk analysis, calculating the cyclone and flood risk to the exposure dataset, as if it were designed to be resilient to a range of Standards of Protection (e.g. resilient up to the 1 in 10-year return period flood hazard, and 1 in 50 years return period cyclone/wind hazard).
- Resilience Metrics - Development of metrics to demonstrate the benefit (or cost benefit analysis) of investment in resilience of power transmission and distribution assets.
- Documentation of the process of fund allocation and utilisation for disaster preparedness, response, and recovery during and after the impact of cyclones. Identification of systemic bottlenecks that create gaps between fund allocation and fund release in post disaster situations.
- Documentation of pre-disaster activities undertaken by the Dept. of Energy in power sector to expedite recovery and reconstruction. This may include pre-agreed supply arrangements, emergency procurement guidelines, rate contracts, arranging for the availability of cash for labour and materials etc.

Some of the aspects outlined above are detailed in the subsequent chapters.



2

Worldwide Disturbanes and Hazard Incidences On Power Utility Network

Interconnection of the power utility networks, integrating the different state grids regional grid, regional grids into national grid, national grids into multi-country grid like European grid, North American grid, Latin American grid, African grid etc. has resulted in the better utilization of the natural resources, optimization in the infrastructure, enhancing the security and stability of the grid. However, this interconnection has also resulted in affecting the major population when un-foreseen grid disturbances occur. Table 1 gives the major gird disturbances in the last 2 decades worldwide and the number of population affected. It can be observed that with higher interconnection, if the grid disturbance results in the major cascaded tripping in the network, more and more population are vulnerable to such disturbances. Each grid disturbance has resulted in the past through investigation of the incidence, improving the resilience of the grid by taking corrective measures. For example, post 2003 North American grid collapse, emphasis on the reliability and power system protection is looked into. India has seen the major grid disturbance in the year 2012, which has resulted in the strengthening of the grid, application of volt-var control through SVC and STATCOM, better deviation settlement mechanism to have discipline in the grid, establishment of protection database management system in few regions supported by protection audit and protection studies and implementation of wide area measurement system (WAMS) and its applications for better visualization of the grid.

Table 1: Major grid disturbances across the globe

Sl. no	Black out	Population affected - Millions	Country	Incidence date
1	2023 Pakistan blackout	230	Pakistan	January 23, 2023
2	2022 Pakistan blackout	200	Pakistan	October 13, 2022
3	2022 Bangladesh blackout	140	Bangladesh	October 4, 2022
4	2021 Pakistan blackout	200	Pakistan	January 9, 2021
5	2020 Sri Lankan blackouts	21	Sri Lanka	August 17, 2020
6	2019 Venezuelan blackouts	30	Venezuela	March 7, 2019 – July 23, 2019
7	2019 Java blackout	120	Indonesia	August 4 – 5, 2019
8	2019 Argentina, Paraguay & Uruguay blackout	48	Argentina, Paraguay, Uruguay	June 16, 2019
9	2016 Sri Lanka blackout	21	Sri Lanka	March 13, 2016
10	2015 Turkey blackout	70	Turkey	March 31, 2015
11	2015 Pakistan blackout	140	Pakistan	January 26, 2015
12	2014 Bangladesh blackout	150	Bangladesh	November 1, 2014
13	2012 India blackout	620	India	July 30 – 31, 2012
14	2009 Brazil & Paraguay blackout	60	Brazil, Paraguay	November 10 – 20, 2009
15	2005 Java–Bali blackout	100	Indonesia	August 18, 2005
16	2003 Northeast blackout	55	Canada, United States	August 14–28, 2003
17	2003 Italy blackout	56	Italy, Switzerland	September 28, 2003
18	2002 Luzon blackout	40	Philippines	May 21, 2002
19	2001 Luzon blackout	35	Philippines	April 7, 2001
20	2001 India blackout	230	India	January 2, 2001

Extreme weather events are impacting the electricity infrastructure, and power generation. Extreme weather events include extreme storm events, heat waves, extreme cold events, sea level rise, floods, droughts and wildfire. Due to climate change, these extreme weather hazards are projected to increase in frequency, intensity and duration in the future. Extreme weather events have resulted in the increase in the costs of power interruptions and damages to electricity infrastructure [4]. Some of these extreme weather events occurred in the past both in globally and specific to India are highlighted here.

2.1 Cyclone hazards

Hurricane Laura (Year 2020): was a powerful category 4 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that made landfall near Cameron, Louisiana, USA, accompanied by a devastating storm surge of at least 5 metres (17 feet) above ground level. It was responsible for 47 direct deaths, in the United States and on the Island of Hispaniola, and more than US$ 19 billion in damage.

Hurricane Dorian (Year 2019): In August was a Category 5 hurricane on the Saffir-Simpson Hurricane Wind Scale, and the strongest hurricane on record in the northwestern Bahamas. More than 200 lives were lost. Dorian caused catastrophic damage mainly in Abaco and eastern Grand Bahama Islands with total damage estimated at $3.4 billion (USD).

Cyclone Gita (Year 2018): Tropical Cyclone Gita passed over the Tonga tapu and ‘Eua island groups starting around 11 pm on Monday, 12 February 2018.The total effects of the cyclone are estimated at $7.9 million, consisting of $6.2 million in damage to power sector infrastructure and $1.7 million in losses to TPL, mainly from loss of revenue. About 95% of the total damage to Tonga Power Limited (TPL’s) power network assets were on Tonga tapu.

2020, Cyclone AMPHAN: The recent super cyclone Amphan hit the coastal areas of West Bengal (Digha) on 20.05.2020 with exceptionally high wind speed reaching up to 175 km/hr. The very Cyclone resulted in serious damage to critical infrastructures and disruption of critical services in 9 coastal districts of Odisha out of which four (4) districts were badly affected. The wind speed was reported to be more than 120km/hr along with heavy rainfall. The distribution infrastructure, particularly 33 kV, 11 kV and LT lines and Distribution Transformers suffered heavy damage. About 275 nos. of 33kV feeders, 1627 nos. of 11kV feeders, 126540 nos. of DTs, and about 44.57 Lakhs of consumers were affected, out of which 13 Lakhs consumers were severely affected. Five (5) towers had collapsed & four (4) towers got deformed.

2019 Cyclone Fani: The severe cyclonic storm „Fani" of 2019 caused huge damage to infrastructures resulting in disruption of critical services in 14 districts of Odisha. The massive damage to power Distribution infrastructure included about 450 substations, and 66,000 distribution transformers, about 41,000 km of sub-transmission lines and 72,000 km of distribution lines. Similarly, the transmission system had also suffered large scale damage, which included about 160km of 220kV line (with damage of 75 nos. of towers), 90km of 132kV line (with damage of 33 nos. of towers) and 31 nos. EHV substations.

2014 Cyclone Hud Hud: Cyclone Hud Hud made landfall on 12th October 2014. It impacted as many as 15 districts of the State of Odisha. The distribution infrastructure, particularly 11 kV, 33 kV and LT lines and Distribution Transformers suffered heavy damage due to cyclone Hud Hud and subsequent rainfall. A massive 700,000 consumers were affected and 239.95 km of 33 kV lines, 2155.99 km of 11 kV lines, 1088.75 km of LT lines, 1754 distribution transformers and 8 power transformers were damaged. The wind speed was 80-100 kmph.

Cyclone Phailin (Year 2013): The Very Severe Cyclonic Storm (VSCS) 'Phailin' made landfall at the coast of Odisha near Gopalpur in Ganjam district on October 12, 2013. Eighteen out of the thirty districts in the state were affected by the storm and subsequent floods. The majority damages were due to high speed winds of up to 220 kmph The cyclone left 44 people dead, damaged about 256,600 homes and affected about 13.2 million people in over 18,370 villages. Estimated damage to power infrastructure is about 1048crore INR. The power Transmission and Distribution infrastructure was severely affected among all the other public infrastructures. A total of 1756 feeders, 38,997 substations, 36,133.9 km of LT (low tension) line, 4074 km of EHT (extra high tension) line and 211,014 electric poles got damaged due to the combined effects of the cyclone and floods. Furthermore, seventy one (71) towers of 220 kV and twenty one (21) towers of 132 kV were damaged. A total of 38.09 lakh consumers were affected.

2.2 Icing an Snowfall hazards

Reference [6] gives the detailed study on the icing hazards. As per this reference, icing is a severe natural disaster of electrical power transmission lines. It has caused severe losses to the transmission systems in many aspects and has brought serious threats to power system stability and even human energy security. In 1932, the United States recorded the first accident caused by icing on overhead lines in human history. This was followed by ice damage to transmission lines in Britain in 1935 and 1962 and in Italy in 1964. Since then, icing disasters have occurred on transmission lines between 1980 and 2000. The U.S. cities of Ohio, Chicago and Idaho, Quebec, and Ontario of Canada, Russia, Norway, Yugoslavia, Japan, the United Kingdom, Sweden, Finland, and Iceland suffered power transmission line failures caused by snowing and icing. Since the beginning of the 21st century, the Czech Republic, Alberta, and Canada, all had also occurred serious icing disasters on power transmission lines. In 2005 and 2008, China experienced two severe snow and icing disasters on transmission lines, which caused significant economic losses. In February 2021, an icing disaster occurred on the power grid in Texas, USA, resulting in millions of people without power.

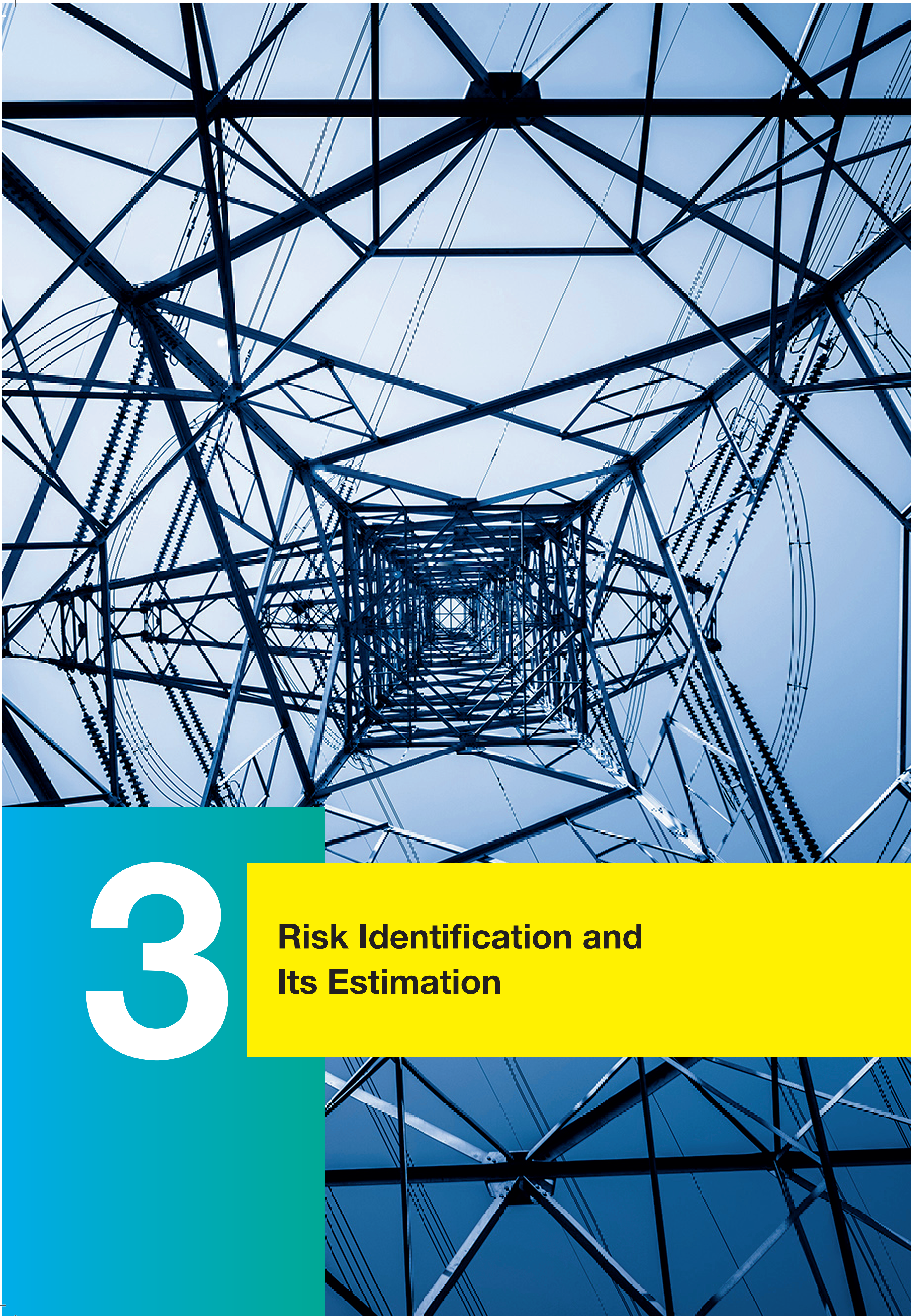
2.3 Seismic hazards

Power outages are a common occurrence during and after major earthquakes. Electricity is typically interrupted during or immediately after the shake. The epicentral area is affected, but adjacent areas may also suffer outages. The duration of the outages in any area is a function of the level of damage to the substations and power lines which serve the area. Following the earthquake, power is restored progressively. Depending on the intensity of ground motion and the level of damage, the duration of the blackout for most customers may range from a few hours to months [8].

Indo-Nepal earthquake (Year 2015): Nepal and Northern India including Bihar, Uttar Pradesh and West Bengal are impacted. More than 8,600 people dead in Nepal,17 people died in Bihar, The loss estimated is of Rs. 33,500-35,000Cr INR.

2.4 Forest fires

As detailed in reference [5], in the Western U.S., hotter and drier weather is associated to higher tree mortality and lower vegetation moisture, creating conditions prone to severe wildfires. Fire risk indicators, such as the Canadian Fire Weather Index, are registering the highest warning signs seen in the last 30 years. Canada, Spain, Portugal, Greece, and Chile have all seen deadly wildfires, causing billions of dollars in damages. British Columbia also has faced devastating losses as fires burned over three and a half million acres. In 2019 and early 2020, wildfires burned over two million acres in the Brazilian Amazon, and over 25 million acres in Australia. High-severity fires have hit California particularly hard in the past decade. Fifteen of the twenty most destructive wildfires in the state's history have occurred in the past ten years; six of the twenty deadliest wildfires occurred in 2017, 2018, and 2020. In late October 2019, several blazes precipitated the evacuation of more than 200,000 people. 2020 saw the highest acreage burned on record, the largest single fire, and the largest fire in California history [5].



3

Risk Identification and Its Estimation

The main objective of Risk Identification and Estimation is to identify, map and assess the extent of hazard risk and vulnerabilities with respect to power infrastructures in the power sector. This exercise involves the following steps -

i. **Baseline Diagnosis:** Identification of vital natural hazards in the power infrastructures; primary data collection from relevant stakeholders; learning's from secondary literature review, understanding First, Second and Third-order risks, current situation analysis, and assessment of steps taken by government for climate change.

ii. **Multi – Hazard Risk and Vulnerability Mapping and Assessment:** Assessment of hazard intensities across the State; Preparing the Zonation Maps.

iii. **Exposure Analysis and Future Exposure Projection of Multi Hazards:** Based on the past incidences identifying the extent of failures and projecting that to the future.

iv. **Asset Prioritization Assessment:** Current and planned future power infrastructure components in the State.

v. **Gap Identification for data/information**: To build power sector resilience and recommendations for better risk identification.

vi. **Potential Recommendations:** For better data management for risk identification.

3.1 A case study on Risk Identification and its Estimation

In this section, a case study on the risk identification and its estimation with reference to the development of cyclone resilience system in the State of Orissa is described.

Methodology and findings

The tropical cyclones bring considerable damage to the structures and loss of life in coastal areas of Odisha. Cyclone Micro-zonation is a step forward to identify asset at cyclone risk. The micro zonation classify larger region into micro zones with varying wind speeds. Micro-zone helps in site-specific hazard analysis which also gathers input for infrastructure design and land use management.

Using the wind speed values at each grid points for different return periods, the micro-zonation maps were obtained using GIS tool IDW which converts the point data to raster image format. The maps were further smoothened to remove any singular discontinuities in order to obtain zonal distribution of wind speeds along the state. Cyclone zonation for different return periods (5, 10,25.50,100) were prepared. The Gust speed map with 50-year return period is considered for analysis

Cyclone Zonation Map of Gust Speed with 50-year and potential power assets exposure to cyclone zone is presented in figures 1 and 2.

Exposure of Asset, Vulnerability & Risk Assessment

It is also worthwhile to note that not all exposed infrastructures are equally vulnerable. Vulnerability is a function of degree of exposure, sensitivity, and adaptive capacity. Certain Infrastructures may have relative better adaptive capacity to cope with the impact of cyclones or flood hazards. To assess the vulnerability, list of physical indicators for transmission substation, lines and distribution lines and sub-stations were examined. Sixteen suitable indicators were selected; each indictor was assigned score in 1 to 4 scales. High scores represent high vulnerability. Assigning equal weightage cumulative score was classified low, medium, and high vulnerable.

Vulnerability Assessment

A hazard vulnerability assessment (HVA) systematically evaluates the damage that could be caused by a potential disaster. The severity of the vulnerability facilitates in pre disaster planning and allocation of resources.

Distribution Substation

30 percent vulnerable distribution substation are located along the seacoast (<20 kM). Among those located close to sea coast, 23 percent of substation at higher order of vulnerability than other substations near to the coast. Distribution sub-station of Kendrapada (79 percent), Balasore (93 percent) and Puri (27 percent) are at relatively higher vulnerability than other coastal districts.

Distribution Line

The determinants of vulnerability stems from weak design of supports of the distribution lines. The 80 percent of poles are either Joist, PSC designs that are susceptible to intense wind speed. Relatively less vulnerable pole design like NBLS / H-Pole/ Rail/ Tower (Lattice) are observed for close to 12 percent of the total supports used in the network. Similarly, the increase in span length increases the susceptibility of power line. Span length of 70m or more observed in 80 percent of 33kV line that increases the vulnerability. Ageing infrastructure compound the impact with nearly to 3/4th of distribution lines reportedly commissioned 30 years earlier.

Transmission Grid Substations

More than half of relatively high vulnerable substations are located between 0-20 kM from the shoreline, indicating the exposure to probable high wind speed with varying degree of vulnerabilities. The vulnerability score assigned on type of GSS; GIS or AIS, supply source Ring or Radial type, control room design standard and year of commissioning. Cumulative score determined vulnerability score of substations AIS substations are predominant common in coastal areas, 54% are ring distribution power systems and close to 1/5th (19%) reported failure history increases the vulnerabilities of substation. 50% of highly vulnerable substations are located 20 kM from shoreline. 24 percent of highly vulnerable fall between 20 to 60 kM from shoreline.

Figure 1: Cyclone Zonation Map - (Gust Speed - 50 year Return Period)

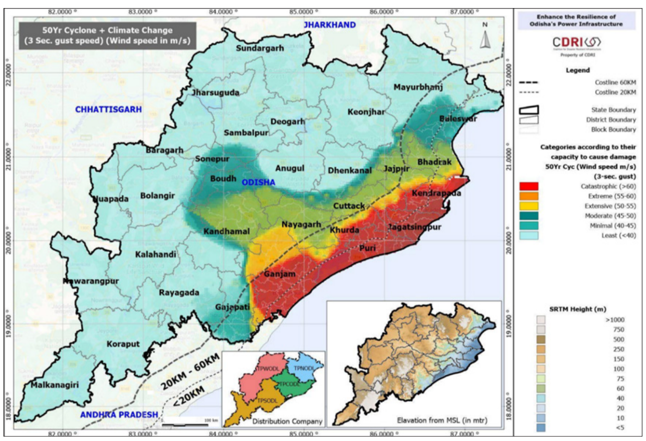
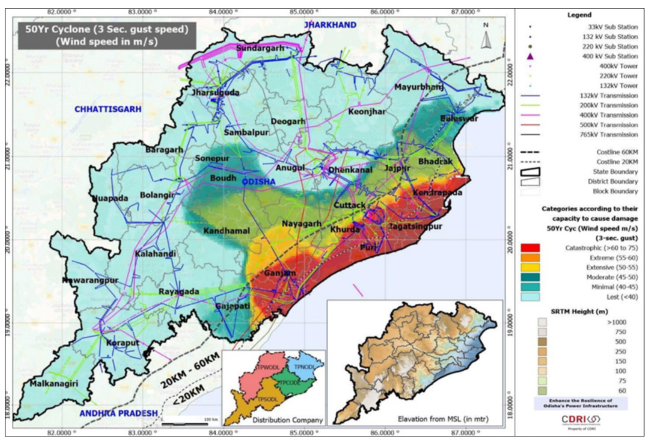


Figure 2: Exposure of Power infrastructure - (Gust Speed - 50 year Return Period)



Transmission line Vulnerability

Transmission vulnerabilities are assessed for network within 60 kM from the coastline. Transmission line vulnerability were assessed using three indicators: Span length, Double Circuit/Single Circuit and age of infrastructure. As tower details were not included due to paucity of data information. Span length more than 250m observed in 32 percent of the line, 48 percent of single circuit line transmission. While at the aggregate level close to 9 percent of highly vulnerable transmission line are within 20kM from the shoreline. 12 percent of highly vulnerable network fall between 20 to 60 kM from the shoreline. In contrast to distribution line, 3/4th of the transmission line are operating within the service life.

Identification of Critical Components

Critical lines serving to essential establishments like water supply, telecommunication service, health care service, transportation and rescue operation, District administrative buildings etc. During cyclones/ flood, these essential services jeopardize without power and affect the rescue operation severely. So it is utmost important to identify the critical lines and respective substations which are feeding power supply to these essential services.

Prioritization of Critical Components

Critical lines and substations those are exposed to high risk are identified based on the study and analysis. In this study, based on the vulnerability and criticality analysis, lines and substations are prioritized for retrofitting/ modification of its components in order to resist the multi hazard risks.

Figure 3 represents prioritization of critical 33kV lines and PSS, Figure 4 represents prioritization of critical 11kV lines and Figure 5 represents prioritization of critical Transmission lines in T&D system of Odisha. Lines and substations identified under different priorities, need immediate attention to verify its wind speed withstand capabilities conforming standards and codes.

Figure 3: 33kV lines & PSS

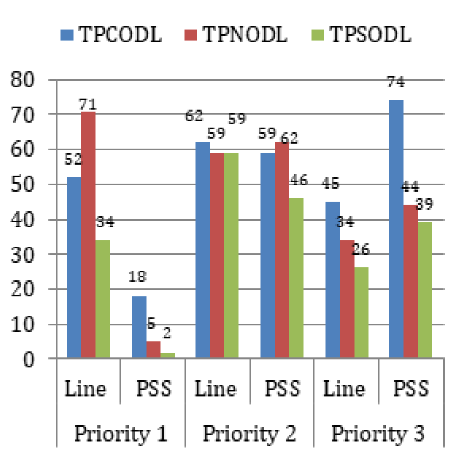


Figure 4: 11kV Lines

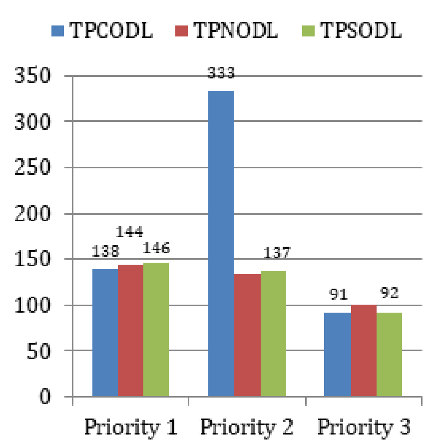
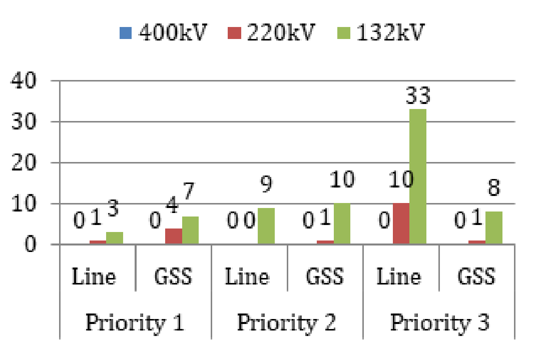


Figure 5: Transmission lines and GSS



Systematic recording Damage assessment

The data on damages to infrastructure from past disaster events (such as cyclones and flood) are partial and scattered or not collated. Damage information with images needs to be systematically collected and hosted in a digital GIS format in the central repository of Discom. Spatial informed damaged assets facilitate in better design innovation and improve preparations for future events. It is also recommended future disaster assessment, systematic spatial assessment according to the Post Disaster Need Assessment frameworks prescribed by the Global Fund for Disaster Risk Reduction (GFDRR).

Spatial Asset inventory and data updating

Spatial assets inventory of Power transmission network is available for the state of Odisha. Digital asset inventories of distribution assets are being planned/ongoing by the respective DISCOMs. These are forward looking initiatives. The spatial database is to be further used and updated with routine repairs of the assets, and additional new assets are to be recorded spatial repository. The annual data inventory audit to be regularized.

Recommendation

India is geographically divided into six wind zones based on long-term meteorological data. For the coastal states in particular, the frequency of occurrence of cyclones along the coast has been different. Therefore, wind zonation for the coastal states-based warrants attention. Based on micro wind zonation, vulnerability of critical power infrastructure needs to be identified and prioritized for strengthening. Like wind zonation, flood zonation and vulnerable assets are to be mapped and priorities for necessary strengthening.

4 Role of Codes, Standards, Regulation and Design

The Adoption of mechanisms required for developing, enforcing, and updating scientific standards and regulations for infrastructure resilience considering changing technology and risk profile is an important task. Sound technical standards must be adhered to while building and scaling up the resilience of infrastructure systems. This ensures that infrastructure is equipped to withstand present disasters as well as the impacts of climate change. Standards are a mechanism to assure investors that infrastructure assets are protected.

The Resilience of power infrastructure can be enhanced by developing and updating codes, standards, design and regulations and adopting the new technologies with respect to the risk exposure and its criticality. This exercise involves the following steps -

i. Identification and analyzing existing designs, codes and standards being followed by Transmission utility and DISCOMS for the construction of power infrastructure

ii. Gap analysis in design implemented by the DISCOMs and transmission utility, failure analysis of Power components.

iii. Analysis of power system network design and reliability of system to strengthen the infrastructure by identifying the critical lines and substations while considering the second and third order risk Cost benefit analysis with review and recommendation of retrofitting and for up gradation of the system.

iv. Risk responsive of codes and standards for modification of codes and designs while considering the future impact.

v. Review and analysis of operation and maintenance followed by different stake holders for restoration and implementation of new technologies for monitoring and safety of critical components as shown in figure 6.

vi. After the site visits to assess the extent of damage, the expert committee meeting needs to be arranged where photographs and samples will be examined thoroughly, if required samples can be tested in the laboratory to find their mechanical strength and ageing effect.

vii. The committee report is to be circulated to all concerned. If required one representative from electricity authority can be invited to the committee meeting.

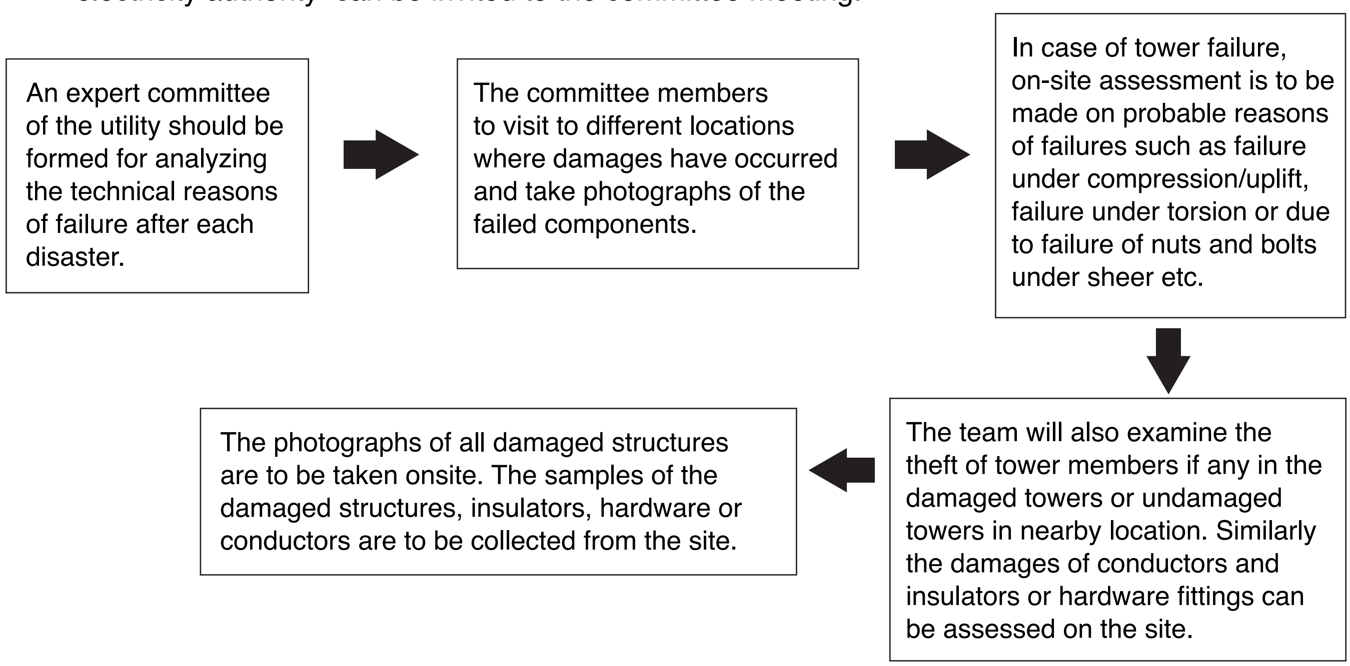


Figure 6: Standard Operating Procedure for technical evaluation of component failure

4.1 Case study on comparison of International Standards with respect to Indian Standard

The wind speeds considered in different countries for designing power infrastructures are furnished in table 1.

Table 2: Designed wind speed in other countries

Sl No.	*Country*	*Designed wind speed in m/s*
1	*USA*	*71.5 - 74*
2	*Argentina*	*60 - 67*
3	*South Africa*	*70*
4	*Canada*	*67*
5	*Australia*	*60*
6	*Bangladesh*	*77.5 - 80*
7	*Philippines*	*75*

- In India, as per the wind map in IS 802:1995/2015, maximum wind speed is 55 m/s.
- As per IEC 60826, the towers are designed for full wind and average every day minimum temperature For Example, the everyday minimum temperature of Odisha will be around 20°C. At the time of cyclone at night, in October end or in November month the temperature goes down to 150C but IS 802 stipulated to consider full wind at 32°C. The full wind at 15°C condition is stringent than full wind at 32°C.
- As per rule 76 of the IE Rules 1956, maximum wind pressure and maximum/minimum temperature are to be specified by the State Government. Now the IE Rule has been super ceded by CEA Safety regulation which says that the maximum wind pressure and maximum/minimum temperature are as specified in the relevant Indian Standards. Instead of taking daily average temperature of 32°C, the average of daily minimum temperature may be considered in the IS in accordance with IEC.
- The drag coefficients stipulated in IS 802:2015 are much less in IEC 60826:2017. Such low values of drag coefficient weaken the towers.

4.2 Disaster Management Policies across the globe

Most of the countries are having their own strategies to mitigate various disasters and have framed policies accordingly. However policies in many countries are more likely similar to strategies and policies followed in India. Following countries have set up their own disaster management plan and policies to tackle various disasters.

a. Brazil

Disaster response in Brazil is highly decentralized and proceeds from the bottom up with minimal coordination from the national government. In the event of a natural disaster, the affected municipality handles its own response. When the scope of the disaster exceeds the municipality's capacity to respond, the regional office is called in, then the state, then the national level. This separation of powers is attributed to the Brazilian legal structure, which ascribes a great deal of autonomy to the state and local governments. At the national level, the disaster management plan is known as the National Civil Defence System (SINDEC). Coordination of SINDEC falls to the National Secretariat of Civil Defence (SEDEC), which is connected to a branch of the Ministry of National Integration.

b. Australia

Australian emergency management sector is one of the most decentralized aspects of government in the country. It relies heavily on trust and the relationships between the federal, state and local governments.

c. Netherlands

In the Netherlands the Ministry of Security and Justice is responsible for emergency preparedness and emergency management on a national level and operates a national crisis centre (NCC). The country is divided into 25 safety regions. In a safety region, there are four components: the regional fire department, the regional department for medical care (ambulances and psycho- sociological care etc.), the regional dispatch and a section for risk and crisis management. The regional dispatch operates for police, fire department and the regional medical care. The dispatch has all these three services combined into one dispatch for the best multi-coordinated response to an incident or an emergency. It also facilitates in information management, emergency communication and care of citizens. All regions operate according to the Coordinated Regional Incident Management system.

d. USA

In the USA, because of geographical differences throughout the country, a variety of different threats affect communities among the states. Thus, although similarities may exist, no two disaster management plans will be completely identical. This creates a plan more resilient to unique events because all common processes are defined, and encourages planning done by the stakeholders who are closer to the individual processes. In the United States, all disasters are initially local, with local authorities, with usually a police, fire, or EMS agency, taking charge. If the event becomes overwhelming to local government, state emergency management (the primary government structure of the United States) becomes the controlling emergency management agency. Federal Emergency Management Agency (FEMA), part of the Department of Homeland Security (DHS), is lead federal agency for emergency management. The United States and its territories are broken down into ten regions for FEMA's emergency management purposes. FEMA supports, but does not override, state authority.

e. Japan

Disaster management in Japan is vested on 3-layered system – national, prefectural and municipal layers. Disaster management system of Japan has undergone tremendous advancement throughout the past 5-6 decades. Disaster Management Councils established at each level and each council is responsible for the implementation of all disaster management related issues under its authority.

The Central Disaster Management Council (CDMC) consists of the prime minister, the chairperson, Minister of State for Disaster Management, all ministers, heads of major public institutions and experts. The council promotes comprehensive disaster countermeasures including deliberating important issues on disaster reduction according to requests from the Prime Minister or Minister of State for Disaster Management. Duties of the council include formulating and promoting implementation of the Basic Disaster Management Plan and Earthquake Countermeasures Plans, formulating and promoting implementation of the urgent measures plan for major disasters, deliberating important issues on disaster reduction according to requests from the Prime Minister or Minister of State for Disaster Management (basic disaster management policies, overall coordination of disaster countermeasures and declaration of state of disaster emergency) and offering opinions regarding important issues on disaster reduction to the Prime Minister and Minister of State for Disaster Management.

f. Bangladesh

Cyclone Sidr has hit Bangladesh in November 2007, it not only caused the deaths of around 3,400 people, but also led to one of the largest blackouts ever recorded: 75 million people lost access to power, which translated into 1.9 billion customer-hours of lost electricity services. Long and widespread power outages such as these have major consequences for people's health and well-being. Among other effects, they impede access to refrigeration for food and medicine, as well as the ability of firms to provide people with goods, services, jobs, and income.

In Bangladesh Natural shocks account for a far smaller share of power outages – not because energy systems are more resilient, but because system failures and non-natural factors are so frequent that energy users experience daily outages. In Chittagong, a major coastal city in Bangladesh, storms are estimated to cause only four percent of all outages (Rentschler, Obolensky, and Kornejew 2019). In Dhaka, the World Bank's Enterprise Survey suggests that there are about two outages per day on average throughout the year; only during the storm season in April and May are outages significantly more frequent. In other words, a fragile system is vulnerable not only to natural hazards, but also to a host of other stressors and shocks that include unmet demand, equipment failure, and accidents.

Still, natural hazards can be responsible for a large number of disruptions. Power systems in developing countries are more vulnerable to natural disaster than those in richer countries. Aging equipment, lack of maintenance, rapid expansion of the grid, and insufficient generation capacity are all factors that reduce the reliability of service in general – but also increase the system's vulnerability to natural disaster.

The higher vulnerability of power systems in developing countries means that even frequent events have large, disruptive impacts. In Bangladesh, severe cyclones damage power plants, renewable resource infrastructure, and power distribution networks. Even relatively frequent storm events, such as the nor'westers occurring around April each year, significantly increase the incidence of power outages. These storms, known for their localized but violent gusts and lightning strikes, tend to significantly damage power transmission and distribution systems, as illustrated by a recent event in March 2019, after which 6,000 communication towers lost access to power.

Ref: Resilience and Critical Power System Infrastructure, by: Amy Schweikert Lindsey Nield Erica Otto Mark Deinert, World Bank report.

5 Technology And Innovation For Resilient Power System

The prime focus of designing a resilient power system is to emphasizes the use of technology to enhance the efficiency of disaster risk management efforts in all stages of disaster management cycle. Usage of new technologies calls for

- Documentation of current materials, technologies, and designs being used in power system for pre, during and post disaster events.
- Analyzing the steps taken by concerned utility to build a resilient power infrastructure in terms of technology and Innovation systems.
- Identification of gaps in the existing system with respect to global practices.
- Recommendations on technology and Innovations for improving the power infrastructure and disaster risk management.

5.1 Current practices of Technologies being used

Following are the technologies being used during the three stages i.e. pre, during and post disaster scenarios. The various technologies and their implementation in many disaster prone areas are listed below:

a) Early Warning Dissemination Systems (EWDS)

b) Satellite Phones

c) Emergency Restoration System (ERS) Towers

d) UG Cabling system for T&D system

e) Ring Main Units (RMU)

f) Compact Secondary Substations

g) RLP, Spun and H type pole for distribution system

h) RCC Spun Poles

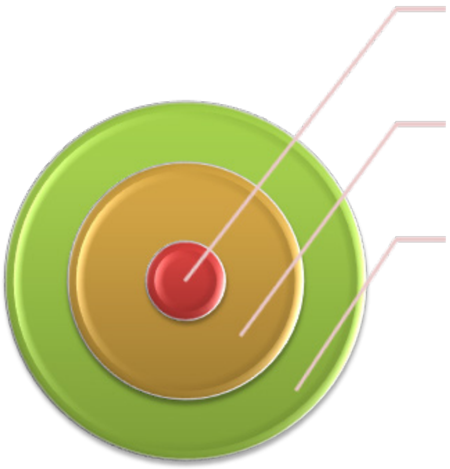
i) Indoor GIS PSS and GSS

j) E-house 33/11kV GIS PSS

5.1.1 Early Warning Dissemination Systems (EWDS)

The primary purpose of Early Warning Dissemination System (EWDS) being implemented in the utilities/ States is to establish a full-proof communication system to address the existing gap of disseminating disaster warning up to the community level by strengthening of State Emergency Operation Centre (SEOC), District Emergency Operation Centre (DEOC) and Block Emergency Operation Centre (BEOC) thereby ensuring information dissemination from the State, District and Block Levels to communities and vice versa, so that the last person living nearest to the sea is well informed to take appropriate action in case of a disaster. The Technology of EWDS involves

- Integrating different technologies for effective dissemination of disaster warnings in a single platform to reach the last mile up to community level and also fishermen in sea.
- The technology involves Satellite based mobile data voice terminal at SEOC and DEOCS; Digital Mobile Radio (DMR) connectivity to SEOC, DEOCs, BEOCs and FLCs; Alert Towers at different locations in coastline for both cyclone & tsunami warning dissemination; Mass Messaging from SEOC for cyclone & tsunami warning and universal gateway for inter-operability; Warning System for DISCOMS.



Emergency: For emergency situation, the siren will be wailing sound 3 times for 30 seconds with a gap of 5 second after every 30 seconds

Disaster: For emergency situation, the siren wil be wailing sound 5 times for 30 seconds with a gap of 5 second after every 30 seconds

ALL Clear: For all clear situations, the siren will be straight run sound for 2 minutes.

Figure 7 Warning System for DISCOMS

5.1.2 Satellite Phones

Communication plays an integral role in disaster management. The Response and Recovery phase needs more information and communicative means. All conventional methods of communication including land phone and cell phone, which connects through a terrestrial network, could be down during and post disaster period. Moreover, most mobile telephone networks operate close to capacity during normal times and large spikes in call volumes caused by widespread emergencies often overload the system just when it is needed the most. The satellite phone or sat phone operates directly through geo-stationery satellite and therefore can avoid this problem and provide failsafe communication in any eventuality.

Figure 8 Sat Phone

5.1.3 Emergency Restoration System (ERS) Towers

Many utilities are using ERS Towers for restoration to extend the power temporarily till the damage towers are reconstructed. During any disaster events, instruction are given to all responsible personals to arrange and provide necessary tools and tackles (welding/ cutting sets, chain pulley blocks, ropes, water pumps, diesel generators etc.) and personnel to operate the same but there is a vast gap in providing the new technology support or system for quick restoration.

Emergency restoration systems (ERS) are modular aluminum towers used to quickly restore power on damaged power transmission lines and facilitate scheduled maintenance work with a minimal power interruption. These are temporary structures that can be erected in 2-3 days, as against several weeks required for permanent restoration of the towers. ERS holds high significance as occurrences of tower failures have increased over the past few years. In the international scenario, the concept of standardizing ERS was started in 1982 in the USA, and the IEEE guidelines were in place by 1995 that many other countries have already adopted. Still, ERS was not indigenously developed in India so far. ERS available in western and developed countries are patented technologies, and their procurement costs are enormous.

Figure 9 22okV ERS Towers

Figure 10 400kV ERS Towers

5.1.4 Underground Cabling System

UG Cabling of important feeders is already installed in many state utilities in transmission and distribution sectors.

132kV, 33kV and 11kV feeders which come under high priority zones in urban areas can be converted to UG Cabling system. Most of the trunk lines should be connected between two sources for alternate power supply during exigencies. Cable trench can be either direct buried or through prefabricated half cut Hume pipes depending on the availability of RoW.

Figure 11 Pre-fabricated half-cut Hume pipes (Typical trench)

5.1.5 Ring Main Units (RMU)

RMUS are one of the most important cyclone resilient equipment, which ensures uninterrupted power supply to the region even during disasters. RMUs are combination of SF6 Circuit Breakers and Load break switches. Provision of operating with at least two incoming sources in the circuit. The number of LBS and Circuit breakers are designed as per the distribution schemes with provision of SCADA automation in future. RMUs play an important role during exigencies. It restores power supply in case of failure in either source.

Figure 12 Ring Main Units

5.1.6 Compact Secondary Substation (CSS)

630kVA CSS are mostly used in coastal cities such. Normally such CSS are proposed at urban areas in the UG cabling system. CSS are housed with Transformer, 11kV RMU and LT distribution panel with FRTU for SCADA automation. These DTs are fully protected from outer forces and safe to operate both remotely and locally. Different sizes of CSS can be designed at specific locations mostly at higher capacity substations are advisable. Alternatively, for small DTRs, existing DT can be placed on Prefabricated foundation with single LBS and LT panel and can be controlled in-group.

Figure 13 Compact Secondary Substations (CSS)

5.1.7 H-Type GI Poles

H-Type Poles are one of the most cost-effective structures which can withstand wind speed up to 260 kM/hour and are reliable to use in coastal areas. It can be erected at any congested area with less space as compared to NBLS towers or DP structures. Two Galvanized GI channels are rigidly embedded each other to form a single structure.

This type of pole is extensively used in costal DISCOMS in India and shown good results in few cyclone incidences. H-Poles can be used for all voltage levels in distribution system.

Figure 14 H-Type Pole

5.1.8 RCC Spun Pole

The Spun Pole is manufactured through a high speed spinning process by which the concrete is homogeneously mixed and this centrifugal spinning results in high density concrete pole with a hollow design. This type of pole is widely used across Visakhapatnam City under Andhra Pradesh and newly adopted in Balasore city under Odisha state of India.

Figure 15 Spun Pole

5.1.9 Indoor Gas Insulated Substations (GIS)

Many utilities have installed good number of GIS in their respective regions, which are mostly indoor and highly resilient to Cyclones.

Figure 16 220/132kV Gas Insulated Substations

5.1.10 E-house 33/11kV GIS PSS

E-house technology of 33/11kV PSS is completely cyclone resilient and mainly chosen at urban areas, which can be installed in less space. Cost of this type of PSS is very high as compared to conventional AIS PSS.

Figure 17 E-house at Bhubaneswar

Figure 18 E-house at Unit-2, Bhubaneswar under TPCODL

5.2 Monitoring of T&D infrastructure and restoration during post disaster

For monitoring of power Infrastructures, distribution companies are generally using vehicles for verification purposes by physically reaching at sites. After an event occurs the damage assessment team rushes to the sites to evaluate the extent of damage inflicted. The role and responsibility of the assessment team is as follows,

A Disaster management system should work in line and co-ordinate with other departments, as below.

The Role and responsibility of each department and team should be clearly defined in the disaster management plan of DISCOMs and accordingly the system should work during any disaster events. Disaster events can be typically classified into three categories. i.e. Level-1, Level-2, Level-3. The detail classifications are described in Table 5.

Table 3 Risk Level							
Level	*Weather Data*			*Transmission Network*	*Flood Information*	*Consumers Affected*	*Interruption*
	Alert for Kalbaisakhi	*Alert for Cyclone*	*Temp. Forecast*	*Transmission network Non availability*	*Flood Alert*	*No of consumers affected*	*No of Interruption*
Level-1	*Low*	*62-87 kM/hr*	*> 400 C for atleast 5 hours*	*Interruption in DISCOM / TRANCSO leading to load shedding of 100 MW for 1 Hr*	*Affecting 2-3 Divisions*	*<50000*	*< 20 DB*
Level-2	*Moderate*	*88-117 kM/Hr*	*> 450 C for atleast 6 Hrs. (Heat Wave)*	*Interruption in DISCOM/ TRANSCO system leading to load shedding of 200 MW for more than 1 Hr.*	*Affecting 4-8 Divisions*	*<100000*	*20-50 BD*
Level-3	*Heavy*	*118 -165 (Very Severe) /166-220 (Extremely Severe) / >220 (Super cyclone) KM / Hr*	*> 470 C (Severe Heat Wave)*	*Interruption DISCOM/ TRANSCO leading to load shedding of 300 MW for more than 1 Hr.*	*Affecting more than 8 Divisions*	*>100000*	*>50 DB*

6

Modern Technologies Used For Risk Mitigation In Infrastructures

Worldwide, modern technologies listed below are used for risk mitigation in power infrastructures.

6.1 Smart Grids and Innovations

Demonstrating a battery-based energy storage system for load shifting, peak shaving, renewable system integration, and support for micro-grid operations.

Figure 19 battery-based energy storage system

6.2 Cloud VMS (video management software)

Cloud VMS can be hosted on AWS S3 for redundancy and data security but can also be deployed on a private cloud. The deployment of pure cloud surveillance is scalable and flexible as additional cameras can be easily added into the system when expansion is required. The built-in cloud analytics enable users to set fully customized, rules-based functions with subsequent custom alerts for email or app push notifications during a set schedule for select users.

“Utilities are part of critical infrastructure and need to have constant awareness of what is going on at their remote sites. This is not only to protect utility workers and the public from physical harm and ensure the reliable supply of electricity that is essential to support our well-being.

Figure 20 Cloud based visualization monitoring software

6.3 Sub-Transmission Recloser

High-voltage pole top recloser supports faster overcurrent protection through fault isolation and automatic restoration for temporary faults on overhead sub-transmission lines. G&W Electric, a global supplier of electric power equipment, developed its Viper-HV recloser up to 72.5kV. The first high-voltage pole top recloser supports faster overcurrent protection through fault isolation and automatic restoration for temporary faults on overhead sub-transmission lines.

Figure 21 Sub-Transmission Reclouser

6.4 Infrared Thermography Power Line Inspection

Utilities can use infrared technology to scan and identify problems with transmission lines and other electrical equipment. When components of electrical systems begin to fail, a common symptom is a significant temperature difference between ailing components and their surroundings.

Using infrared technology, utilities can perform fast and efficient preventative maintenance on large areas of transmission circuits. Routine infrared scans of critical equipment can help avoid emergency restoration efforts by identifying problems prior to failure.

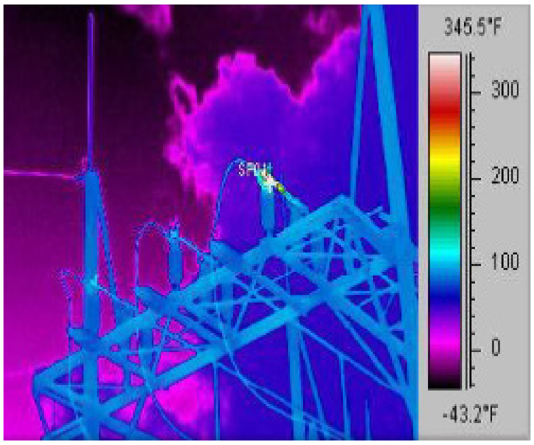


Figure 22 Infrared Technology

6.5 Smart switches

Electric utilities are not only making their systems more resilient through a focus on system hardening and vegetation management, but they are also rolling out new technologies to expedite restoration. For example, Ever source has installed smart grid equipment such as “smart switches” to enable system operators to isolate power outages and remotely reroute power from another source within minutes.

Additionally, smart fuses automatically restore power to customers when a tree limb temporarily contacts wires and help to protect the electric system when a problem is detected. Also, optical ground wire (OPGW) enhances communication between company facilities and protects the high-voltage transmission system from severe weather conditions, such as lightning strikes.

At AEP, crews have installed “smart circuit” technology to speed restoration by pinpointing a fault location and automatically switching customers outside the damaged area back in service. More than 20 of AEP’s West Virginia distribution circuits have this technology in operation, and several more projects are underway.

6.6 Mobile Transformers and Substations

\Mobile transformers and substations can be used by utilities to temporarily replace substation transformers in the low and medium power range (10-100 MVA) that are damaged by a hurricane.

Figure 23 Mobile Substation and Transformer

6.7 Mobile Generator

Truck-mounted mobile emergency generators (MEGs) are critical flexibility resources of distribution systems (DSs) for resilient emergency response to natural disasters. However, they are currently under-utilized. For better utilization, As the travel time of MEGs on road networks (RNs) can greatly influence the outage duration of critical loads, a two-stage dispatch framework consisting of pre-positioning and real-time allocation need to be done.

Figure 24 Mobile Generator

In past years, extreme weather events have frequently occurred, causing significant economic losses to Society. For example, the earthquake and tsunami in Nepal and Chile caused the loss of power supply to many customers for several consecutive days in 2010. In 2012, Hurricane Sandy caused a blackout that affected 8 million customers, with an estimated loss of 75 billion. In 2017, Hurricane Harvey caused an outage of 10,000 megawatts in Texas, affecting 291,000 customers. Electric vehicle fleets, mobile energy storage (MESS) systems, electric buses and mobile emergency generators are widely used as mobile power (MP) sources. It is proposed to dispatch MEGs in the distribution system to restore critical loads by forming multiple micro grids. MEGs can be connected to Distribution systems as a source of supply which is disconnected from the main substations during disasters. However as the investment on MEGs are costly the main objective should be to minimize the economic losses caused by load outages [11].

Source: https://www.sciencedirect.com/science/article/pii/S2352484721014244

6.8 Composite Utility Poles

Composite utility poles are made from fiberglass reinforced polymer composite material. They provide an alternative to traditional wood, steel, or concrete poles, and have several advantages over other materials. The composite poles are:

a) Lighter

b) More impact-resistant

c) Resistant to rot or decay

d) Free of toxic preservatives

e) Non-conductive

f) Virtually maintenance free

g) Cyclone resilient

Figure 25 Composite Poles

A specific advantage over steel poles for coastal regions is that they are corrosion resistant and will not rust. Although composite poles have existed for many years, cost and susceptibility to ultraviolet light have prevented widespread commercialization. In recent years, however, material costs have come down due to advances in fiberglass technology and ultraviolet issues have been addressed by advances in polymer chemistry. Composite poles have typically been used for distribution lines and for transmission lines (70-to-80 foot tall poles) are also becoming available. Such poles are cyclone resilient and widely used in America.

6.9 Use of Drones to monitor Power Infrastructures

Electric utilities in many countries are investing in technologies to prepare for severe weather. Also, they are using aerial inspections with drones and helicopters to pinpoint damage and more quickly mobilize line crews following a cyclone.

“Drones allow utilities to quickly patrol power lines during a cyclone in areas when they are otherwise not accessible by foot or by vehicle,” Drones provide images and details damage in those areas, making the damage assessment process more efficient so that the line workers can get their job done quicker. Among its significant potential, drones as an advancement of commitment to safety by minimizing the need to put humans at risk with electrical hazards.”

Figure 26 Drone system for Inspection of lines

6.10 Dynamic Line rating (DLR)

The Dynamic Line Rating (DLR) of OHL uses the fact that the ampacity of OHL depends on ambient conditions and the OHL is designed for high summer weather conditions. As less severe weather conditions exist for most of the year, the ampacity of the existing lines can be significantly increased (up to 200%). The major task thereby is to derive the present and forecast the future ambient conditions, calculate the current carrying capacity, and integrate these results to dispatch center processes, considering adequate security margins.

Figure 27 DLR in Power Line

6.11 Gas Insulated Lines (GIL) AC

In Gas Insulated Lines (GIL), the inner conductor is located in a pipe the approximate diameter of which is 50cm. It is kept central using disc or support epoxy resin insulators. The pipe is filled in with insulating gas. Compared to OHL and underground cables, the electric and magnetic field is very low. Nowadays, GIL is mainly used in short lengths within substations, in densely populated areas or to connect industrial/power plants to the transmission network transferring current.

Figure 28 Gas Insulated Lines

6.12 Vehicle to Grid (V2G)

V2G is a technology that allows for bidirectional energy flow, enabling energy stored in EV batteries to be pushed back to the electricity grid. The essential idea is to modulate the charging and discharging of EV batteries in accordance with the users’ needs and the demands of the grid. EVs could charge to their maximum level or change their rate of charging when the supply is high and subsequently, EV batteries could inject electricity back to the grid during peaks in consumption or in response to grid demands thereby serving as temporary energy storage units. V2G also offers scope for incorporating a greater share of intermittent renewable energy (RE) in the grid by allowing EVs to act as decentralized storage units during periods, which are conducive for increased RE production.

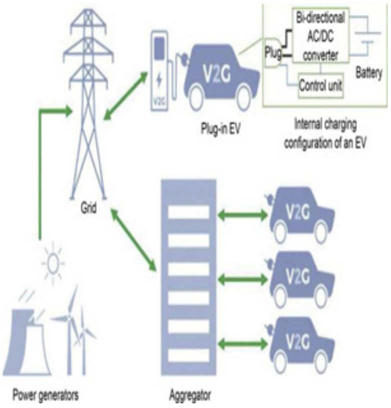


Figure 29 V2G block diagram

6.13 Distribution-level BESS for Resilience Services

A Distributed Battery Energy Storage System (D-BESS) is a system where battery storages are distributed throughout a power grid. This type of system has many benefits over a centralized system, where all of the batteries are located in one place. One benefit is that it is much easier to maintain and repair a D-BESS than a centralized system. Another benefit of a D-BESS is that it is much more resilient to power outages. This is because if one battery fails, the others can still provide power. When opted the BESS for resilience support mainly, the same can be used for all other use-cases under normal weather conditions while reserving for extreme weather conditions. BESS can be economically feasible by stacking the multiple use cases of BESS.

The following are the potential D-BESS use cases understood from the international review suitable for Indian context.

- Increased system resilience and reliability, including islanding of critical infrastructure and facilities during extreme weather conditions.
- Energy Arbitrage (Peak Load Management)
- Reactive power/Voltage support
- Distribution upgrades deferral.
- To support the integration of DERs (Distributed Energy Resources) and EVs (Electric Vehicles)
- To minimize Deviation Settlement Mechanism charges
- The displacement of diesel generators in urban and peri-urban environments.

A storage system can effectively support customer loads when there is a total loss of power from the source utility due to any extreme weather conditions. This support requires the storage system and customer loads to island during the utility outage and resynchronize with the utility when power is restored. The energy capacity of the storage system relative to the size of the load it is protecting determines the time duration that the storage can serve that load. This time can be extended by supplementing the storage system with on-site Solar PV generation that can continue supporting the load for long-duration outages that are beyond the capacity of the storage system. The analysis can be focused on substation level or feeder level for BESS location while estimating the BESS to support for resilience of the system. The sizing of the BESS (capacity in kWh/MW and storage hours) can be determined by estimating how many hours or days the system can run independently to serve critical loads with support from local PV generation.

6.15 Virtual Power Plants

An emerging aspect of developing alternative electricity supply sources is to use technology to centrally control power generation from multiple alternative (often-backup) sources connected across a power system. This practice has been referred to as virtual power plants, which include the aggregated control and trading of distributed generation and load in order to mimic the operation of a large power stations contribution to the power system. The dispatch and payment of the many small contributions is centralized. Virtual power plants differ slightly from micro-grids in that they are not generally designed to operate in aggregate in a group islanded from the national grid.

One practice that appears to be emerging is the monitoring and aggregation of standby generation plants owned by third parties that maintain the standby capacity for their own business continuity. With advances in communication, aggregation and control in response to appropriate pricing tariffs are resulting in standby plants being used on the grid to benefit the owner and many others.

Many commercial enterprises and essential services have backup diesel generator sets for their own purposes. During system events, these resources are often underutilized. The aggregated dispatch of this generation plant can, in some cases contributes many hundreds of megawatts of grid connected generation capacity. The functioning of this cutting edge engineering solution requires extensive infrastructure; it is not yet suitable for developing countries as it is still in development. Pilot examples include combined power plants, which link and control 36 wind, solar, biomass, and hydropower installations spread throughout Germany (Enercon GmbH, Schmack Biogas AG and Solar World AG 2007; Solar Server 2014).

6.16 Artificial Intelligence in Emergency Management Exercises

Most disaster management preparation is done through preparation of emergency plans, board games, role plays, and emergency drills. These exercises inevitably involve assumptions and subjective assessments since it is difficult to replicate real-life conditions, including stress impacts in decision making. They become even more restrictive when they try to capture complex disaster scenarios (as opposed to individual and isolated incidents). The stakeholders being trained are not put in crisis situations, and training exercises do not include a dynamic feedback loop. Using artificial intelligence (AI) in disaster management simulation plat forms is an emerging tool in risk preparedness. While this type of tool does not replace emerging management exercises, it can enhance the value of training exercises.

The AI system replaces the propagation of the disaster, its impact on people and infrastructure, and the actors involved in terms of victims, emergency responders, and their materials. In addition to enhancing the value of emergency management training, the AI system also validates existing and theoretical disaster plans and procedures. It can also be used as a total or partial alternative to a large scale emergency management exercise, which can be quite expensive or disruptive to business operations.

6.17 Wireless Power Transmission

Wireless communication would be the transmission in the energy spanning a distance without the usage of wires or cables, where distance can be short or long. Wireless operations permits services, for example long-range communications, which are merely unfeasible using wires. Wireless energy transfer or wireless power transmission may be the transmittance of electric power from power source for an electrical load without interconnecting wires.

Figure 30 : Wirelessly transmitting electric power (Source: https://newatlas.com/energy/)

A New Zealand-based startup Emrod has developed a method of safely and wirelessly transmitting electric power across long distances without the use of copper wire, and is working on implementing it with the country's second-largest power distributor. It has taken 120 years, but New Zealand company Emrod appears to have finally convinced a major power distributor to have a crack at going wireless in a commercial capacity. Powerco, the second-biggest distributor in New Zealand, is investing in Emrod, whose technology appears to be able to shift large amounts of electricity much more efficiently, between any two points that can be joined with line-of-sight relays.

6.18 OMS, GIS and SCADA

The Outage Management System (OMS) and the Geographic Information System (GIS) are the central core business functions for modern power disruption restoration activities of transmission and distribution utilities. These vital systems enable command center operations to access and understand situational information in real time.

GIS has become the foundation of distribution system documentation because its map based database is perfectly suited to tracking geographically dispersed assets and monitoring their status. By keeping the GIS database up to date in real time, operators can prioritize areas of the network to target for repair, and crew dispatchers can monitor progress.

As a geographically and visually based asset management system linked with operational data from field applications and live SCADA, GIS provides rapid insight and understanding not previously possible. It also enables simple communication of information to third parties.

Mobile applications for damage assessment linked to the GIS assist operators in understanding the cause of an outage, the assets impacted, and the extent of asset damage. Image capture and safety issues can be automatically uploaded to GIS and work dispatch applications. The live updating of GIS is revolutionizing incident management and response.

By predetermining such critical areas as essential services, work plans can be prioritized and optimized. This technology provides a way to better understand the level of effort required and the resources and materials that are available. Better quality data results in improved decision making. When crews complete asset restoration, they upload the new information, including images, to the work management system, enabling the next technical discipline to work on the faulted assets or the control centre staff to place the assets back into service.

Mobile applications (apps) are being used increasingly for installation and operational maintenance Using computers and smart phone technologies, these systems can retrieve real time data from a GIS when a user points the mobile device at distribution equipment such as a pole or transformer. Data relevant to the equipment (e.g., drawings, equipment order details, and circuit overviews) can be downloaded to the field crew. Recovery crews can then tag equipment for repair and replacement, and estimate time to restore.

The mobile apps enable crew locations and crew equipment and stock to be tracked so that capable teams can be dispatched efficiently to problem areas ideally close to them. When constraints arise, nearby crews can be contacted to assist with staff or equipment.

The next step with more switching is more visibility of the network in real time. To repeat, this practice was adopted decades ago by some utilities; with the improved communication systems now available, utilities are extending their communication networks and visibility and remote network control of their SCADA systems. By linking the SCADA system to the GIS system, richer data becomes available. Improved visibility is providing better damage assessment, improved work prioritization and scheduling, and improved customer results as more accurate restoration times can be provided.

Utilities can use advanced metering infrastructure to gather distribution network conditions. By interrogating remote smart meters, utilities can better understand the outage status of network components. Even with a power supply outage, many smart meters can indicate their supply point status by sending a “last gasp” status indication before losing their ability to communicate and another status indication when power is restored.

Other relatively new means of improving power system visibility include the addition of phasor measurement units (PMUs), networked power quality analysers, and utilizing the SCADA and monitoring functions of modern digital protection relays. By connecting such technologies to utility WANs (wide area networks) and ultimately the utility SCADA systems, the understanding of a power systems condition and behavior is improved.

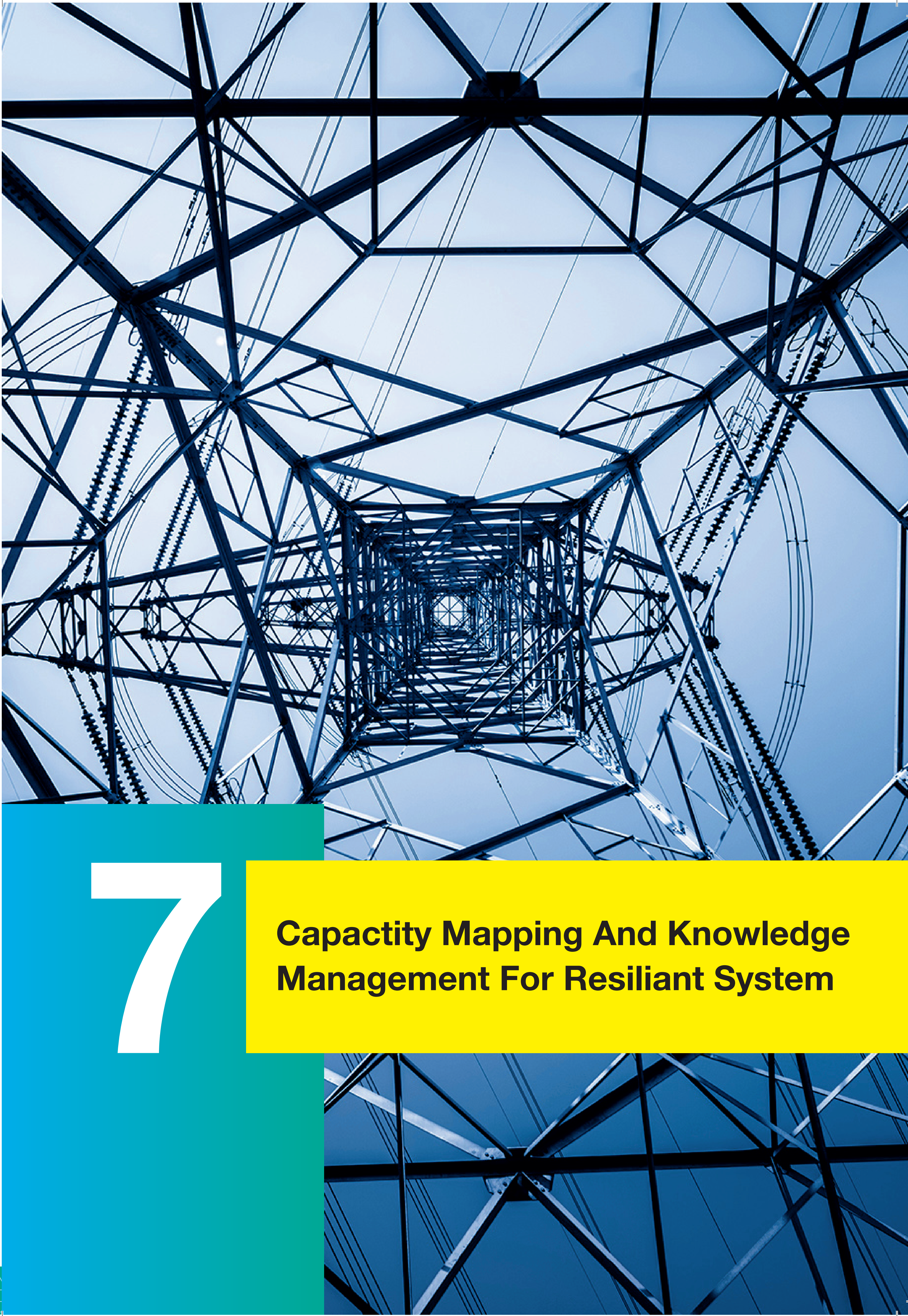
Improved real time situational awareness and control of grid equipment enhance the utility’s ability to reduce the impacts of major disruptions and speed up restoration efforts. Status indications of individual customers increase a utility’s situational awareness, enabling it to personalize messages to individual customers or groups to help them make informed decision.

6.19 Potential Recommendations Orissa Case Study

Based on the detailed analysis/examination of the technologies, recommendations are presented in the State of Orissa as in table 4.

Table 4: Recommendations

Activity	*Recommendations*
Technology & Innovation	*H-Type poles, Spun poles, Under Ground Cabling system, Ring Main Units (RMU), Compact Secondary Substation (CSS), Gas insulated Substation (GIS), Fault Passage Indicators (FPI) are to be adopted in selected areas.*
	SCADA systems are to be extended to all 33/11 kV substations.
	Smart Grid in urban area (municipalities and corporations) and smart meter installation to be initiated.
	GIS mapping of all electrical assets across the utilities.
	Solar systems with sufficient storage capacity are to be encouraged. Rooftop PV cells need to be installed in hospitals, water supply systems, telecommunication towers, collectorate office etc. so that in case of non-availability of power supply from the grid, emergency power supply can be availed from the solar system. The PV cell supporting structures should be strengthened to withstand the high wind speeds. They are designed to be modular and easily dismountable when cyclone warning comes.
	Un-manned Aerial Vehicle (UAV)/Drones can be engaged for damage assessment immediately after cyclone, monitoring the vegetation growth on both sides of the line. Even the line restoration works can be monitored with UAV.
	Using remote technology to accelerate and promote cost effective inspections of distribution poles in high risk areas, substations and T&D lines.
	Using technologies such as Micro Grids, renewables, mobile sub-station, Mobile Generators, advanced distribution management systems, autonomous drone usage and real-time analysis.
Risk Assessment	*Isolating critical assets and equipment during disruption events (e.g. using smart automated switchgear) to reroute power and improve grid resilience.*
Restoration, Recovery & Reconstruction	*During restoration, if the damaged poles are replaced by the same type of poles, this may lead to further failure during cyclones. Hence, restorations are to be made as per new design for 260kM/hr.I.e. damaged joist pole/PSC pole to be replaced by H-Pole in 33kV&11kV lines and by Spun Pole/H porcelain LT Lines as per the requirement.*



7

Capactity Mapping And Knowledge Management For Resiliant System

Capacity Building for disaster management includes the following action items:

(i) The Identification of existing resources and resources to be acquired or created.

(ii) Acquiring or creating resources identified as above

(iii) Emphasizes the organization and training of personnel and coordination of such training.

Capacity building actions comprise curriculum development, large-scale awareness, mock drills, response exercises, and human resource development through individual and organizational training. Sectional areas to conduct capacity building in power sector utilities include –

- The adaption of resilience electricity infrastructure and vulnerability assessment study.
- Public awareness programs, Mock Drill Exercises, and Media relations.
- Mainstreaming of disaster risk assessment, mapping, and management in development plans and programs.
- Training on response and recovery, Emergency Restoration Systems (ERS), the rescue of equipment at all levels, black start facilities and teams' responsibilities.
- Early warnings, maps/ satellite data for effective dissemination of information.
- Planning capabilities to ensure coherence of build back better with overall development efforts and goals.

Table 5 General approach to Disaster Management Training

Sl. No.	Training Programs on	Key Component	Target Audience
1	Awareness and sensitization on Best Disaster Management practices with the existing resource	• Planning for deployment of the technical and non-technical groups during the exigency. • Checking the available tools and allotment to each group	• Superintending Engineer, Executive Engineer, SDO and Junior Manager of the concerned area
2	Training and Development Skill	• CEA guidelines relating to safety and electric supply • Use of safety tools during a disaster	Executive Engineer, SDO and Junior Manager of the concerned area. Trainings can be Trainings to be bifurcated based on categories like O&M, Rate contract holders, Repair manpower, GIS experts etc.
3	Preplanning of material Procurement and Services	• Ear Marking of Budget • Delegation of financial power for Disaster Management	Superintending Engineer, Executive Engineer of the concerned area
4	Approach for restoration of power supply on priority	• Restoration of power supply on priority according to the nature of Public Service of the Institution	Executive Engineer, SDO and Junior Manager of the concerned area
5	Training Program on Safety	• Mock Drill	All Electricity Staff officers and Contractors

Ensuring that disaster risk reduction is a national and local priority with a strong institutional basis for implementation requires building institutional capacity through the development of policy, legislative and institutional frameworks. The transition from critical infrastructure protection to critical infrastructure resilience is brought by changes in risk landscape and an increase in uncertainties. A multi sectorial system approach is important for building the resiliency of critical infrastructure to engage stakeholders in design, investment, construction, ownership, operations or regulation. In many of these envisioned roles, the government comes out as an important player.

7.1 Capacity Building Initiatives for Disaster Management Activities for the Power Sector

Aforementioned segment signifies capacity mapping of trained permanent and contractual staff on aspects of disaster risk reduction. The flexibility of deciding during unexpected conditions includes strong human resource and management processes that provide the tools for middle management to make timely decisions during a disaster, and additionally trained personnel exemplifies an effective preparation against threats. Capacity Building activities needed to implement before facing any hazard that may affect adversely includes key components –

- Planning for deployment of the technical and non-technical groups during the exigency.
- Checking the available Tools and allotment to each group.
- Country's electricity authority guidelines relating to safety and electric supply.
- Use of safety Tools during the disaster.
- Earmarking of budget
- Delegation of financial power for Disaster Management.
- Restoration of power supply on priority according to the nature of the Public Service of the institution.

Beneficiaries of capacity development at the state level include government officials of disaster management and power sector organizations and at the DISCOM level Superintending Engineers, Executive Engineers, SDO and Junior managers of the concerned areas are trained. In terms of disaster management, building the capability of an institution's personnel and stakeholders is critical.

7.2 Assessment of Knowledge Management Landscape in the Power Sector

Knowledge Management (KM) is a multidisciplinary approach to attain the desired objectives by creating, sharing, using, and managing information as well as the technology of an organization.

Knowledge Networking is envisioned as an initiative to establish networks and partnerships among prime government agencies, policymakers, disaster managers, and specialists from allied fields of engineering, architecture, planning, seismology, hydrology, agriculture, and social science to exchange information and work together to reduce risk.

The knowledge management initiative of Government of India involves a web portal to facilitate the knowledge collaboration between the network members. The portal provides tools to capture or acquire and organize knowledge. It also provides facility to find and share knowledge through the portal. Basically, it provides an independent workspace for States & research Institutions for designing and updating content. The portal is operating on an extranet and controlled by access levels. Users at the various networks are sharing their programme status and progress in the portal.

The portal is capturing the products of the programme such as database of disaster management plans, various manuals, documents, reports, trained human resources information, emergency contact details, hazard and vulnerability maps etc. The portal will have a public interface once it is populated with information. It also contains a List Server which facilitates e-mail and discussion groups. The portal enables cross postings and interactions across the networks

7.3 Recommendation for enhancing knowledge management for power sector

As learning from the Lao PDR case study, the government can consider the involvement of stakeholders from the various departments for power sector resilience policy formulation and planning. Stakeholder involvement also increases the local technical capacity for resilience planning, facilitated consensus building by involving numerous stakeholders across the government and assured that local expertise and institutional knowledge would be accessible to support future resilience planning.

It has been observed that involving local expertise is often a more trusted knowledge source. State can identify local delivery partners to assist in the training activity and throughout the implementation of capacity building activity. Further, a proven example of the inclusion of local experience can be referred from case study 1.

Case Study 1: Safer School Project, Peru

Engineers were engaged as part of the Peru Safer Schools Project to devise retrofitting solutions. These engineers were appointed from the Pontifical Catholic University of Peru and the Peruvian National University of Engineering's Japan-Peru Center for Earthquake Engineering Research and Disaster Mitigation. Furthermore, assistance was given by Colombia's Universidad de los Andes. Leveraging information from regional academic platforms facilitated connections between the Universities and the Ministry of Education and helped establish a supportive atmosphere for DRM. Local experience is usually a more reliable knowledge source than that offered by a third-party advisor.

Source: https://www.gfdrr.org/sites/default/files/publication/evaluation-ucl-reviewing-impact-capacity-building-gfdrr-2016.pdf"

7.4 Recommended system for utilities to develop capacities for power sector

Training objectives and goals for effective disaster management and disaster risk reduction in state comprehend through three-stage perspective plan comprising short term, medium term, and long term plans. The Department of energy or an apex training and capacity building institute for disaster management in the state could be the holding and executing agency for this perspective plan. Three sets of training goals and objectives will be executed in two phases -

Phase 1 - Short term and medium-term training goals and objectives

Phase 2 - Long term training goal and objectives

This multi-stage strategy would train the mass of resources, who can have a decisive influence to build resilience in the overall capacities of the power sector. It is a performance-based cascade training model which will involve the following activities fie

1. Establish a training committee that involves at least one member from each organisation of power sector and government stakeholder, who would further identify training needs, aims and objectives.
2. Develop training modules / TOT modules and evaluation tools. Identify who needs to be trained and the number of people to be trained.
3. Identify at two least master trainers in each organisation to train group of trainers, who in turn would organise direct training programs at the state, district, organization, executive, non-executive, and linemen levels
4. Training would be implemented by clarifying the role of trainers and supplying resources.
5. Designing an evaluation and supervision strategy such as feedback mechanism and performance rating.

Figure 31 Implementation of Training Plan

7.4.1 General Recommendations

Training Programs for youth/local communities -

Local communities and university youth can be trained on disaster preparedness or response activities of the power sector. The government can collaborate with institutions/universities/colleges to provide training to local youth. Under the same concept, NDMA has been running a scheme since May 2016 for training of community volunteers in disaster response namely Aapda Mitra.

Training on New technology includes –

- Installation of the Under Ground Cabling system, Ring Main Units (RMU), Compact Secondary Substation (CSS), Gas insulated Substation (GIS), and Fault Passage Indicators (FPI) in urban areas.
- SCADA systems are to be extended to all 33/11 kV substations.
- Developing Smart Grid technology in urban areas.
- GIS mapping of all assets.
- Use of Un-manned Aerial Vehicle (UAV)/Drones for monitoring the vegetation growth on both sides of the line and restoration work.

7.4.2 Planning and Management of Capacity - Building Activity

Planning and managing of capacity building activity are the most unattended and neglected fragment of documents. Proper documentation of implementation strategy including monitoring and evaluation results in the tremendous success of establishing motives for capacity development.

- Along with local stakeholders, the project manager may devise a plan for capacity-building activities, which will give the client and project manager a clear framework for how the training activity will be implemented.
- Implementing, monitoring and evaluation strategy is a key component to monitoring progress. Including a timely review of training activities and selecting indicators to monitor throughout implementation ensures the effective progress and strong assessment of activities.
- Maintaining manuals and e-learning modules would help create a repository for institutions.
- To monitor the learning and to ensure observations are incorporated into training implementation, a support from knowledge manager or an organization that facilitates knowledge management will attain the identified objective.

8

Policy And Regulations For Resiliant System

Coastal states have always been identified as highly susceptible to occurrence of natural hazards like floods, drought, or cyclone. The North Indian Ocean Basin covering the Bay of Bengal and the Arabian Sea are extremely vulnerable to cyclones and its associated hazards like high velocity wind and heavy rains, and Odisha's location on the east coast of India makes it one of the six most cyclone prone areas in the world.

Power infrastructure has a really important role to play in the various aspects of disaster management, such as disaster preparedness, response, relief, and rehabilitation, and hence it becomes crucial for building resilience of power infrastructure against natural hazards to be prioritized. The power sector is both highly vulnerable to natural hazards and a priority for any country's recovery and reconstruction.

The Disaster Management Act, 2005 provides the institutional and coordination mechanism for effective Disaster Management at the national, state, district, and local levels. As per the Disaster Management Act, 2005 a multi-tiered institutional system was setup consisting of the National Disaster Management Authority headed by the Prime Minister, State Disaster Management Authority headed by the state Chief minister and the District Disaster Management Authorities headed by the District Collectors and co-chaired by the chairpersons of the local bodies. It provides the orientation for handling disaster situations in a holistic, multi-dimensional and multi-disciplinary approach involving diverse scientific, engineering, social and financial processes. The proactive approach of the India Disaster Management encompasses activities like disaster prevention, disaster mitigation, disaster preparedness, disaster response, relief, and rehabilitation. As per Section 46(1)(b) of the Disaster Management (DM) Act, 2005, Under national disaster management fund, central government has allowed contributions from individuals/organizations for mitigation of disaster.

The National Disaster Response Fund (NDRF), constituted under Section 46 of the Disaster Management Act,2005 supplements SDRF of a State, in case of a disaster of severe nature, provided adequate funds are not available in SDRF. The Centre contributes 75% of the SDRF allocation for general category States and Union Territories. It further supplements State Disaster Response Fund (SDRF) in case of a disaster of severe nature, provided adequate funds are not available in the SDRF. The State Disaster Response Fund (SDRF), constituted under Section 48 (1) (a) of the Disaster Management Act, 2005, is the primary fund available with State Governments for responses to notified disasters. Also, National Calamity Contingency Funds are also placed in public account of government of India and are further utilized for meeting the expenses incurred for emergency response, relief and rehabilitation at times of any threatening disaster situations. Also, the Departmental Disaster Management Plan of Energy Department, 2018 further highlights activities that enable the various agencies involved in generation, transmission, distribution, and supply of electricity to plan for timely and efficient response and restoration from the unpredicted incident.

Electricity infrastructure like substations and transmission / distribution lines are designed to operate under differing climatic circumstances throughout the year. However, climate change could pose additional challenges not yet accounted for in current planning and design. Hence, existing codes, standards and regulation need to be examined in view of the severity of the cyclones in the past and large-scale damages in the power infrastructures. It is imperative to improve the resilience of infrastructure through changes in codes and standards, bridging the gap between standards and implementation, improving the O&M practices including vegetation management. Codes and standards also need to fill the gaps based on dynamic changes occurring due to climate change.

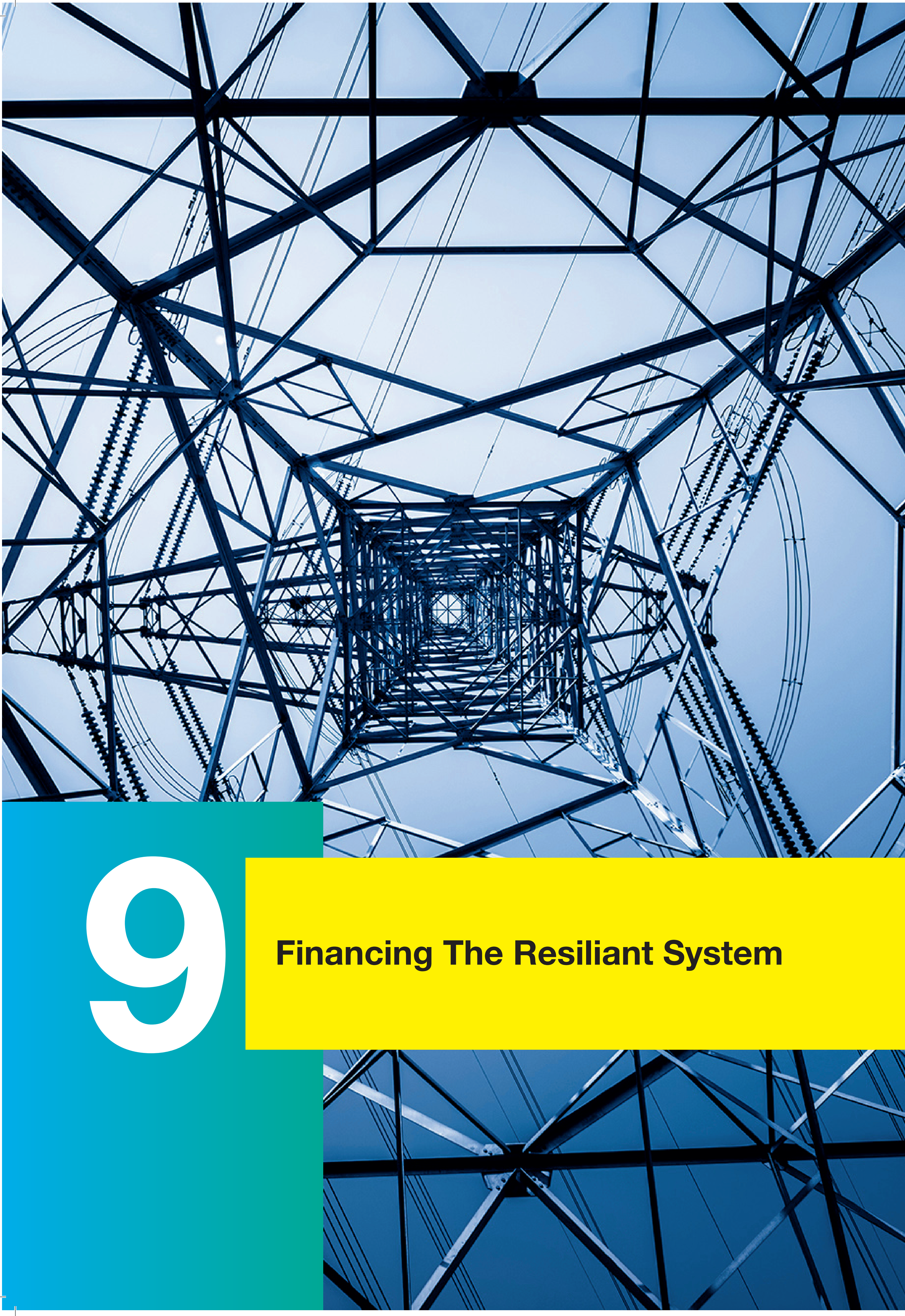
8.1 Best practices: A global approach towards resilience mechanism

Power sector infrastructure is diverse. So is its vulnerability to natural disasters. It is of utmost importance to constantly opt for global good practices with respect to adaptation in existing policies to incorporate infrastructure resilience in power sector and focus on areas to improve the institutional resilience

Cyclones being a recurrent event has caused damage to infrastructure and disruption in the activities of critical infrastructure. The economic and physical losses keep on mounting with every catastrophic event hence it is important to adopt and invest in practices and building strategies providing a resilient and holistic approach aiming toward build a better mechanisms. Hence, setting proper structural measures for critical infrastructure play an important role in disaster risk reduction and further creating resilience with financial preparedness. Also, to be effective, they need to be rational, enforced, and need to be updated regularly to keep pace with the evolving understanding of natural hazards and advancements in engineering technology.

It is important to strengthen the financial and non-financial aspects of designing and standards to regulate a better coping mechanism. Improper regulatory mechanisms can cause disruptions and further increase the cascading impact of the disaster. The best practices opted reflect the need for robust electrical networks ensuring uninterrupted power supply and further enhances the government's ability to mitigate the damages occurring and ensure economic feasibility. Standardization of equipment's and materials and identifying and prioritizing vulnerable areas before setting up of underground cables may be needed to build a resilient power sector. The practices indicate the requirement of a methodical and integrated approach highlighting the inter linkage between proper governance and financial mechanism, which further helps in strengthening the resiliency. States having vulnerability toward various debacles owing to its geophysical complexities require an updated resource to cope with growing climate and disaster risk.

It has become a mandate to have a paradigm shift toward power restoration within the minimum disruption, which itself undermines the scope of building resilience.



9 Financing The Resiliant System

In India, the disaster risk concerns are integrated into the government budgets to ensure that levels of public expenditure on risk reduction are sufficient and that there are adequate financial arrangements to manage the residual risk. This schema of funding for disasters had been expected to provide State Governments with a dependable source of assistance to meet their disaster response, relief, recovery, and reconstruction needs.

As per the Disaster Management Act 2005, each SDMA (State Disaster Management Authority) can establish a State Disaster Mitigation Fund (SDMF), review mitigation works, and approve disaster management plans of the departments. Disaster management, as a subject and as a facet of Union-State relations, has evolved over the years. The initial focus depended on disaster relief, but the Disaster Management Act expanded the area of concern and action of both the Union and State Governments to various disaster management functions, which included relief and response, preparedness, and mitigation, as well as recovery and reconstruction. In India, the disaster risk concerns are integrated into the government budgets to ensure that levels of public expenditure on risk reduction are sufficient and that there are adequate financial arrangements to manage the residual risk. The Disaster Management Act created a new institutional structure for disaster management, with the setting up of the National Disaster Management Authority (NDMA) and State Disaster Management Authorities (SDMAs). The Act also mandated the role of institutions and functions influencing the gradual and incremental strengthening of financial arrangements for disaster management.

This schema of funding for disasters had been expected to provide State Governments with a dependable source of assistance to meet their disaster response, relief, recovery, and reconstruction needs.

As a result, the National Disaster Mitigation Funds do not flow into the SDMF, which would have been beneficial for conducting mitigation work. To further help the state government, funding initiatives such as Energy Resilience Banks (ERBs), catastrophic bonds, and Multilateral Development Banks (MDBs) such as the European Bank for Reconstruction and Development (EBRD), World Bank and Asian Development Bank (ADB) provide grants, loans, equity payments or guarantees for climate-related initiatives, including innovative climate resilience measures. are also available aimed at funding resilience initiatives. The State Government can request loans from international financial institutions such as the World Bank, ADB, and JICA, etc for accessing loans for recovery and reconstruction during the post disaster with necessary approval from the related institutions.

Also, as per the Schedule VII of the Companies (CSR Policy) Rules 2014, the companies may provide funds set up by the Union Government or State Government for socio economic development and relief. This can be leveraged by the Government to develop incentives to the private sector for improving support for disaster management activities. In India, the optimal combination of regulation and incentives (both financial and non-financial) stimulates resilient recovery. Effective government incentives can be localized depending on the characteristics of each region’s infrastructure and private sector capacity ensuring resilience.

In a significant departure from the past, in the report of the 15th Finance Commission for the Year 2020–21, recommended a new methodology, which presents a combination of capacity (as reflected through past expenditure), risk exposure (area and population), and hazard and vulnerability (disaster risk index) for determining State-wise allocation for disaster management.

As per the 15th Finance Commission recommendation, the National Disaster Risk Management Fund is formed with two types of funding in the area of disaster financing, i.e., National Disaster Risk Finance (NDRF) and the National Disaster Mitigation Fund (NDMF). The total allocation for the National Disaster Risk Management Fund (NDRMF) is segregated among NDRF and NDMF in an 80:20 ratio. The NDRF allocation is further divided into Response and Relief (40%), Recovery and Reconstruction (30%), and Preparedness & Capacity building (10%). (Figure 32)

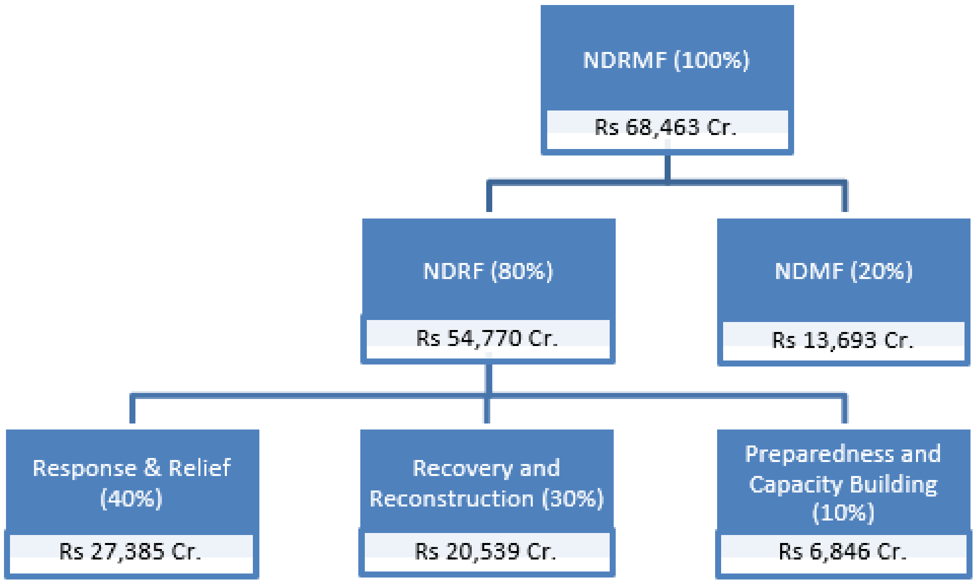


Figure 32 Earmarked Funds for NDRMF as per 15th Finance Commission (2021-26)

State Disaster Response Fund:

The state Disaster Response Fund is a financial resource that meets the expenses of disaster relief operations and restoration of critical infrastructure (power) for a range of specified disasters within the state. The SDRF is constituted in each state with funding from the Central and State Governments. As per the Sec 20 of the DM Act, 2005, the financing of relief measures under SDRF is decided by the State Executive Committee (SEC).

The National Disaster Response Fund:

The State government is the primary responsible institution for undertaking disaster response, recovery, and rehabilitation process in the event of a natural disaster. During the calamity, if additional funds are required, they can be requisitioned from the National Disaster Response Fund as per the procedure. (Figure 33)

Figure 33 Procedure for fund allocation through NDRF

Although, the Ministry of Power provides the relief for the repair of damaged power sector infrastructure of immediate nature, the assistance will be given to damaged conductors, pole, and transformers up to the level of 11 kV as per the norms of assistance issued by the SDRF and NDRF from time to time.

In public finance, disasters are looked upon as a contingent liability of the state. The allocations made through the SDRF and NDRF help governments meet their contingent liabilities. However, the existing approach to meeting the contingent liabilities has two weaknesses. First, it is aimed at meeting the contingent liabilities and not reducing them. Governments should invest in estimating risk exposure and taking appropriate measures to reduce contingent liabilities. Second, the SDRF and NDRF, which function as dedicated reserve funds, are presently the only financial mechanisms for meeting the contingent liabilities.

g. Financial arrangements: Role of major stakeholders

For fund allocation DISCOMS and other stakeholders can submit a detailed assessment report, which is further reviewed by concerned state and central agencies. Once the report is approved, mobilization of funds is carried out (Figure 34)

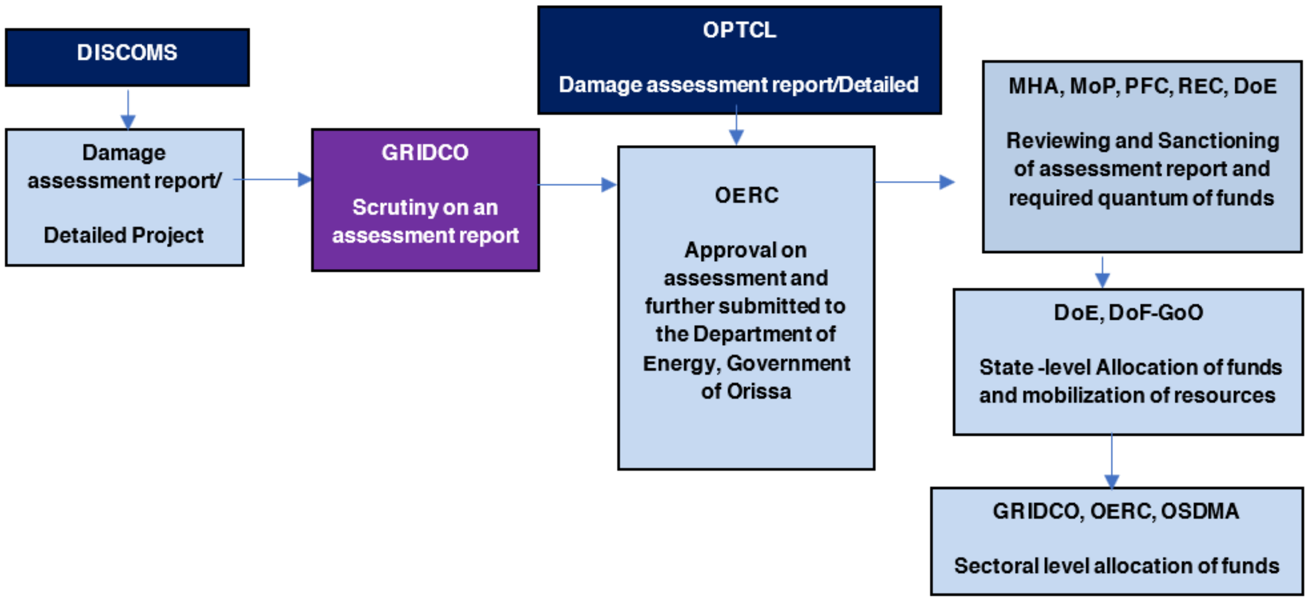


Figure 34 Example; Disaster Financial landscape of Odisha Power Sector

The funds mobilization can be made for certain activities under the Disaster Management Plant such as project financing, disaster resilient infrastructure, and up-gradation of technologies, etc., which will assist in power infrastructure resilience during a natural calamity. For building resilient infrastructure, it becomes crucial that certain policy, institutional, design, and financial considerations should be incorporated in the Reconstruction plans of the Energy Department. Table 6 gives the typical financial assessment conducted by various departments.

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Table 6 Financial assessment conducted by various governing departments

Role and responsibilities matrix				
Departments / Stakeholders involved	Detail Damage Assessment report/ Detailed Project Report	Approval on assessment	Approval on quantum of	Allocation and mobilization of funds-State level Sectoral distribution
MHA		✓	✓	
MoP		✓	✓	
CEA		✓		
REC			✓	
PFC			✓	
DoE	✓			✓
DoF			✓	✓
OSDMA/SDMA	✓			✓
GRIDCO	✓			✓
OERC	✓			✓
OPTCL	✓			✓
DISCOMS	✓			✓

Key References/Disclaimer

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DISCLAIMER

The authors acknowledge the information and knowledge acquired from the open source as references and used in the articles.

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