Cyclone Preparedness for Renewable Energy Projects

General Advisory to Power Sector Utilities with a Special Focus on Renewables

CDRI
Coalition for Disaster Resilient Infrastructure

CYCLONE PREPAREDNESS FOR RENEWABLE ENERGY PROJECTS

4th & 5th Floor, Bharatiya Kala Kendra, 1, Copernicus Marg,
New Delhi, 110001, India

Design: CDRI

Cyclone Preparedness for Renewable Energy Projects

General advisory to power sector utilities with a special focus on renewables (i.e., utility-scale wind and solar power generation projects)

This is a general advisory that contains recommended steps for preparing wind and solar projects for cyclones and high-wind extreme events.

It aims to highlight and suggest key vulnerabilities of such projects and provide mitigation procedures that can be checked as means of protecting valuable assets. The overall goal of the below advisory is to increase the survivability of renewable projects.

Technical risks to the wind and solar projects in the event of cyclone

Figure (1) illustrates the impact and risks to wind power projects in the event of high wind scenarios due to cyclones.[1]

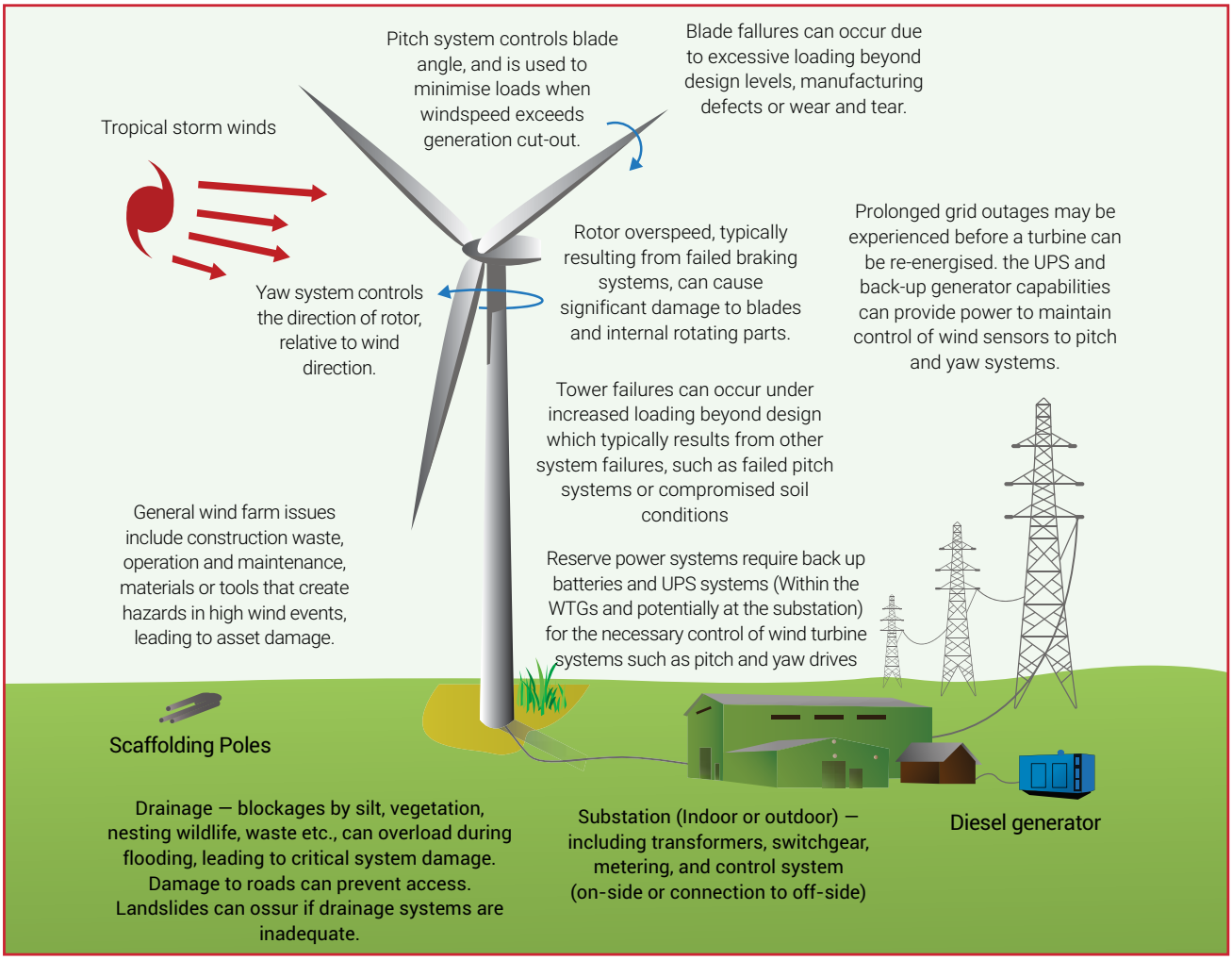

Figure 1: Technical Risks to the wind power projects in the event of cyclone.

1 Tropical Storm Preparedness for onshore renewable energy projects, Axis Renewables and Renewables Consulting Group, 2019, https://www.axiscapital.com/docs/default-source/resources/axis_whitepaper_tropicalstormpreparedness.pdf

Figure (2) illustrates the impact and risks to the solar power projects in the event of high wind scenarios due to cyclones.[2]

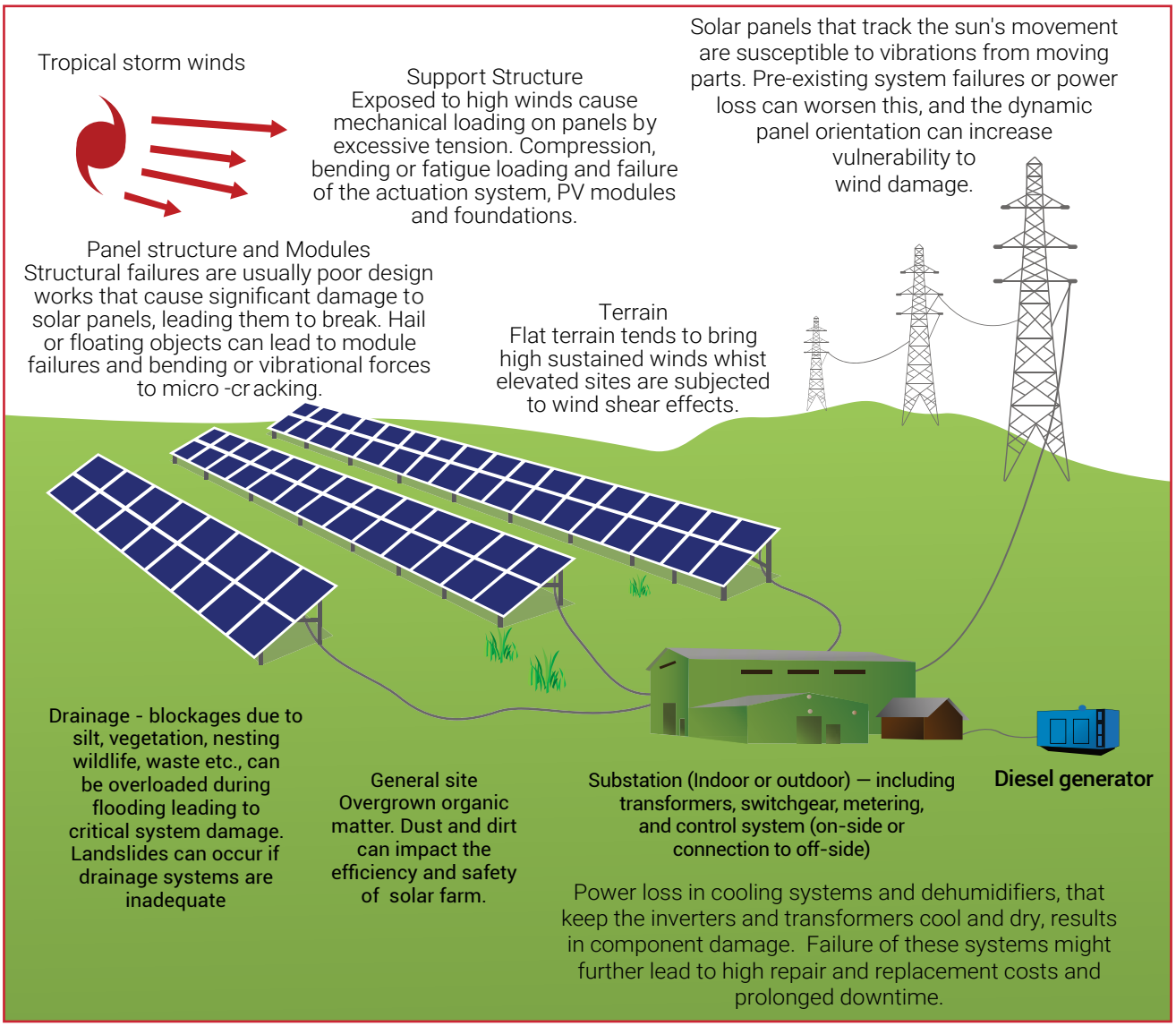

Figure 2: Technical Risks to the solar power projects in the event of cyclone.

General advisory for cyclone preparation for renewable energy projects

Cyclones pose significant risks to renewable energy projects, necessitating comprehensive preparedness plans to ensure the safety of personnel and protect critical infrastructure. Some of the key steps in cyclone preparedness for onshore renewable energy projects include risk assessment, emergency response team establishment, communication and early warning systems implementation, evacuation and shelter planning, infrastructure protection measures, equipment and supplies readiness, training and drills, business continuity planning and documentation..

A thorough risk assessment helps identify potential hazards, such as strong winds, heavy rainfall, storm surge, and flooding, and assess the vulnerability of renewable energy project infrastructure. An emergency

2 Tropical Storm Preparedness for onshore renewable energy projects, Axis Renewables and Renewables Consulting Group, 2019, https://www.axiscapital.com/docs/default-source/resources/axis_whitepaper_tropicalstormpreparedness.pdf

response team comprising project personnel, local authorities, and stakeholders is formed to coordinate efforts during cyclones. Communication systems and early warning systems are implemented to receive and disseminate timely cyclone-related information. Evacuation routes and safe shelter locations are determined, and personnel are educated on evacuation procedures. Infrastructure protection measures are employed to secure wind turbines, solar panels, buildings, and access roads. Adequate emergency equipment and supplies are maintained, including first aid kits, communication devices, and backup power sources. Regular training sessions and drills enhance preparedness and coordination. A business continuity plan ensures minimal disruptions and facilitates post-cyclone recovery. The preparedness plan is documented, reviewed, and shared with relevant stakeholders.

By implementing these proactive and preparatory steps, renewable energy projects can be effectively prepared for cyclones-safeguarding personnel and minimizing damage to critical infrastructure. The advisory is divided into three sections including:

A. Specific checklists for disaster preparedness for wind power projects.
B. Specific checklists for disaster preparedness for solar power projects.
C. General disaster preparedness advisory for the transmission and distribution networks.

A. Specific checklists for disaster preparedness for the wind power projects

Specific preparedness checklists during the operations stage for wind power projects[3,4,5,6]	
Wind project site-normal operations	▪ Generic issues are included in the O&M plan and the emergency response plan (ERP), which would include the below: ▪ To the extent that it is commercially prudent, equipment and personnel for addressing the consequences of a high wind event are available on standby, either on-site (owned by the entity or maintained by a contractor) or via an emergency standby contract. The equipment in question would encompass the items listed below: » Portable generators with an adequate fuel supply, typically through a standby contract with a priority allocation and short notice delivery » Pumps to remove floodwater » Access to suitably qualified personnel for system testing prior to re-energization » Road and hardstanding repair gear » Spill prevention and clean-up measures ▪ Roads, drains, and electrical systems maintenance should be scheduled with consideration of upcoming cyclone seasons, including maintaining clean and empty fuel and chemical bunds.

3 Tropical Storm Preparedness for onshore renewable energy projects, Axis Renewables and Renewables Consulting Group, 2019, https://www.axiscapital.com/docs/default-source/resources/axis_whitepaper_tropicalstormpreparedness.pdf

4 Disaster Management Plan for Power Sector, Central Electricity Authority, Ministry of Power, Government of India, 2023, https://cea.nic.in/wp-content/uploads/ps___lf/2023/01/Disaster_Management_Plan_DMP_2022_for_power_sector.pdf

5 Preparing for Cyclone- Advisory to Power Utilities, Coalition for Disaster Resilient Infrastructure (CDRI), 2021, https://www.cdri.world/upload/pages/1724281555353472_202202091037cdriadvisory.pdf

6 How do Wind Turbines Survives Severe Storms, Office of Energy Efficiency and Renewable Energy, US Department of Energy, 2017, https://www.energy.gov/eere/articles/how-do-wind-turbines-survive-severe-storms

Wind turbine generators (WTG)- normal operations	▪ WTGs should be kept in good working order in accordance with the O&M plans and maintenance programs. WTGs that are not properly maintained, regardless of design and construction competence, may fail at lower windspeeds than they are designed to withstand. ▪ If the WTG supplier identifies additional maintenance requirements as a result of the site's location in a cyclone region, these must be included in the O&M plans and contracts. Otherwise, routine maintenance should be performed, with maintenance activities planned with the cyclone season in mind. ▪ Critical systems indicated below should be in a functional state during the cyclone season: » Back-up power systems » Hydraulic systems » Bolt tensioning and torquing » Blade inspections ▪ Any faults, particularly in the pitch and yaw systems that are critical to cyclone protection, should be identified and corrected as soon as possible, practically before the next cyclone season. If installed, Condition Monitoring Systems (CMS) can identify upcoming outages and schedule repairs or replacements to ensure they do not occur during the cyclone season.
WTG - Specific actions for operational ERP	▪ The shutdown procedure depends on the WTG model, the location and contractual responsibility of the operations and control center, and the integrity of the SCADA system. When separated from the control center, wind turbines work one-sidedly in self-preservation mode. The procedure must be clearly set out for primary and backup scenarios and understandable for all employees. ▪ After the event, the ERP must establish the procedure for declaring the site safe for access and for restoring the site and electrical systems to service prior to returning the WTG to service. ▪ The ERP must include the protocol for restarting WTGs, which is expected to include: » Checking for any structural damage » Checks for blade damage including cracks and lightning strikes » Notification to the Electrical System Operator » Checking of SCADA system » Addressing errors shown, depending on the O&M agreement and manufacturer's handbook » Physical inspection may be required of up to 100% of the WTGs on site prior to restarting » Manual or remote re-starting, as possible ▪ The WTGs are put back into operation by the operator regardless of whether the WTG supplier, an independent operating company, or the owner is commissioned to do so. Each must design their procedures, using the original watchtower procedures as a basis and making them available. The responsible party, their duties, and liabilities as well as the derivation of the procedures used should be checked.

Flooding and Drainage	▪ Conduct ongoing inspection and cleaning of drainage systems as specified in the O&M plan and adjusted as appropriate to accommodate cyclone season. ▪ For a cyclone, the ERP should include pre- and post-storm clearance and post-storm damage assessment. ▪ Drainage may be required after a storm, including pumps that require backup pumps (or contracts for them) with electricity. If the flooding affects the electrical infrastructure, competent personnel are required to test and restore or write off.
Grid contracted obligations	▪ Notification to grid operators is a crucial contracted requirement in the event of curtailment.
Communications	▪ Create a central war room, where the overall monitoring and control of activities like grid supply status, damage to infrastructure, response, and restoration coordination will be undertaken. This should also coordinate and seek regular updates from the IMD and the state disaster management authority on the status of the cyclone. ▪ Formation of core teams across Generation, Transmission, and Distribution utilities in the state, each exclusively looking into the following: » Material procurement and management » Manpower arrangement & Deployment » Logistics/Transportation, Lodging and Boarding etc. » Collection of field Information and MIS preparation/reporting » Coordination with field offices through messengers

B. Specific checklists for disaster preparedness for the solar power project

Specific preparedness checklists during the operations stage of the solar power project [7,8,9,10,11,12,13,14]	
Solar project site-normal operations	▪ Follow the generic technical requirements for most issues, as responsibility has been allocated. ▪ For solar farms check particular attention is given to debris, and surrounding vegetation.

7 Solar Photovoltaic Systems in Hurricanes and Other Severe Weather. U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, 2018. https://betterbuildingssolutioncenter.energy.gov/sites/default/files/pv_severe_weather.pdf

8 Solar Under Storm: Select Best Practices for Resilient Ground-Mount PV Systems with Hurricane Exposure. Rocky Mountain Institute, 2018. https://rmi.org/wp-content/uploads/2018/06/Islands_SolarUnderStorm_Report_digitalJune122018.pdf

9 Solar Under Storm Part II: Select Best Practices for Resilient Roof-Mount PV Systems with Hurricane Exposure. Rocky Mountain Institute, 2020. https://rmi.org/solar-under-storm-part-ii-designing-hurricane-resilient-pv-systems/

10 PV System Owner's Guide to Identifying, Assessing, and Addressing Weather Vulnerabilities, Risks, and Impacts. U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, 2021. https://www.energy.gov/sites/default/files/2021-09/pv-system-owners-guide-to-weather-vulnerabilities.pdf

11 Preparing Solar Photovoltaic System Against Storm, National Renewable Energy Laboratory, 2022, https://www.nrel.gov/docs/fy22osti/81968.pdf

12 Tropical Storm Preparedness for onshore renewable energy projects, Axis Renewables and Renewables Consulting Group, 2019, https://www.axiscapital.com/docs/default-source/resources/axis_whitepaper_tropicalstormpreparedness.pdf

13 Disaster Management Plan for Power Sector, Central Electricity Authority, Ministry of Power, Government of India, 2023, https://cea.nic.in/wpcontent/uploads/ps___lf/2023/01/Disaster_Management_Plan_DMP_2022_for_power_sector.pdf

14 Preparing for Cyclone- Advisory to Power Utilities, Coalition for Disaster Resilient Infrastructure (CDRI), 2021, https://www.cdri.world/upload/pages/1724281555353472_202202091037cdriadvisory.pdf

Solar project site-normal operations	▪ Clear the site of any debris, loose material, or equipment no longer in use (if possible); otherwise, tie down. ▪ Remove delicate instrumentation such as externally mounted pyranometers. ▪ Roads, drains, and electrical systems maintenance should be scheduled with consideration of pending cyclone seasons.
Modules, fasteners, racking, support structures, and active tracking — normal operations	▪ Routine maintenance includes tightening bolts, cleaning panels, and checking panel integrity. It should be verified that the operations and maintenance plan include all activities necessary for maintaining the system as per its design. Determine if additional activities or a specific schedule of activities are planned to accommodate the cyclone season and verify that these changes are being followed. ▪ Ensure that the additional operational and maintenance requirements of active versus passive systems, where applicable, have been addressed. ▪ Check the module for damage, including the front sheet, back sheet, edge seal, and junction box for exposure; replace if possible or ensure the module/string remains unpowered during a storm event. ▪ Document and take images (visual, infrared, electroluminescence) to capture the state of the array before the event. ▪ Check for any missing or corroded fasteners, and replace, if necessary. ▪ Check the torque of fasteners and tighten them according to manufacturer specifications. ▪ Check all hardware for corrosion, missing or damaged parts, and replace, if necessary. ▪ Check torque of the racking hardware and tighten as per the manufacturer specifications, if necessary. ▪ For tracker systems, stow at high wind angle.
Electrical systems (connectors, wiring, and supports) — normal operations	▪ Before conducting any electrical adjustments or modifications, ensure all system AC/DC disconnects, fuses, switches, and circuit breakers are in the open position. ▪ Check J-box is securely attached to the module and is intact. ▪ Check that PV cable connections are securely connected and free of corrosion, and replace, if necessary, avoid cross-mating when possible. ▪ Check system DC wiring for kinks, damage, or exposed conductors, replace if needed. ▪ Inspect any other cable connections for secure contact and corrosion, replace or repair, if necessary, and avoid cross-mating when possible. ▪ Check cable ties, clips, and/or clamps are in place, holding cable securely to the module frames and racking. The cable should not be dangling or loose but should not be pulled taut against metal surfaces that might wear out the sheathing in high winds or damage the connectors. Replace damaged or worn materials with UV-resistant ties and wire clips/clamps (preferably metal and not plastic) on modules and rails, if possible. ▪ If conduit is used, check conduit to ensure it is not damaged and continuous; replace or repair if necessary.

	▪ Check enclosures for structural integrity, corrosion, and water tightness (including combiner boxes, inverter boxes, and battery storage enclosures); replace or repair if necessary. ▪ Check structural mounting of enclosures, tighten to specifications, or replace if necessary. ▪ Check electrical connections in enclosures (including corrosion, and damaged connectors, and check the torque on all bolted power connectors); replace, repair, or tighten if necessary. ▪ Check the grounding system for tightness of connections and electrical continuity of the system. ▪ Check gaskets, conduit fittings, and seals on penetrations in electrical enclosures to prevent wind-driven rain, tighten, and/or apply outdoor rated sealant if necessary. ▪ Ensure access panels to enclosures are closed and latched, when possible. ▪ Install a weep hole in the bottom of the electrical enclosure for moisture to escape.
Solar projects operational ERP	▪ The shut-down procedure for a solar farm is likely to be automated where SCADA is in place. ▪ Check SCADA installation, and ability to report storm damages. Check manual systems where SCADA is not in place. ▪ A check system is in place to put the plant in stowage, and emergency backup systems particularly for power supplies is in place. ▪ Shutdown may also include physical intervention, including placing equipment coverings. ▪ Determine if failure of auxiliary power systems due to water ingress, lack of insulation, and high humidity will trigger an alarm and if a remote reset is possible or a prolonged loss of earnings, partial or total, will be indicated. Likewise, failure of the main network will result in a loss of exportability, even if the site is operational. ▪ Check that the re-start procedure includes: » **Accessing the site** — In addition to the generic safe site access considerations, check specifically for solar farms that consideration is given to further falling debris including panel parts. » **Error clearing and restarting** — Full inspection (looking for cracks, delamination, structural deformation and evident damage) and testing of the regime should be done, either manually or remotely. Stowage angles should be checked for evidence of forced movements. The extent of testing will depend upon the extent of the storm, plus the time the site has been disconnected, and whether backup power has been made available, or the site has been fully shut down. A phased restart may be used for safety and to maximize production. » **Reconnection** — This may be undertaken when technical compliance has been demonstrated to the System Operator, and may also be undertaken as a phased exercise.

Flooding and Drainage	▪ Conduct ongoing inspection and cleaning of drainage systems as specified in the O&M plan and modified appropriately to accommodate cyclone seasons. ▪ For a cyclone, the ERP should include pre- and post-storm clearance and post-storm damage assessment. ▪ Drainage may be required after a storm, including pumps that require backup pumps (or contracts for them) with electricity. If the flooding affects the electrical infrastructure, competent personnel are required to test and restore or write off.
Grid contracted obligations	▪ Notification to grid operators is a crucial contracted requirement in the event of curtailment.
Communications	▪ Create a **central war room**, where the overall monitoring and control of activities like grid supply status, infrastructure damage, response, and restoration coordination will be undertaken. In addition, the central war room should also coordinate and seek regular updates from the IMD and the state disaster management authority on the status of the cyclone. ▪ Formation of core teams across Generation, Transmission, and Distribution utilities in the state, each exclusively looking into the following: » Material procurement and management » Manpower arrangement and deployment » Logistics/Transportation, lodging and boarding, etc. » Collection of field Information and MIS preparation/reporting » Coordination with field offices through messengers

C. General disaster preparedness advisory for transmission and distribution networks

1. Immediate pre-impact activities

Local offices in areas of potential impact

- Create alternate local hubs across impact areas as a backup in case of communication link breakages, and to enable seamless disaster response.
- All hospitals, nursing homes, other medical establishments, banks, along with state departments of disaster management, relief, etc. in the likely impact areas to be contacted by the field engineers to assess the availability of **backup power supply** like DG sets (including sufficient fuel), other storage units and to also check the status of provisioned **secondary supply** (if any).
- Take **immediate stock and create an inventory** list of critical materials like power distribution transformers, LT/HT poles, conductors, ABC cables, location/substation, ERS towers, Cross-Arms, V-Cross Arms, GI Pin, Insulators, etc. which may be damaged due to high-speed winds or flooding or required for post-damage recovery.

Supply chain – Inventory, personnel, tools, and finances

- Take immediate **stock and list the agencies available** (along with their contractual manpower) with the departments involved in capital projects, operations, and maintenance activities. All such agencies may be immediately contracted for restoration works at listed or government approved rates.
- All state-level contractors having **valid electrical licensees** shall be contacted in advance to provide manpower and laborers for assistance in reconstruction work.
- **Financial limits** of field engineers are to be fixed for local immediate procurement, with guidelines specifying the materials that can be procured at the approved rate lists.
- Power Transmission and Distribution utilities to immediately **check availability of equipment** like hydra, pole master, tractors, trucks, buses, emergency lights, marsh boats and diesel gensets (DG) sets (with sufficient fuel) that maybe vital for restoration activities (as per the requirements). If available, the same may be strategically deployed across likely impact areas for commencing restoration works without delay. If these are not available, the emergency procurement team (to be formed) may immediately contact the suppliers for rent/lease/purchase of such equipment along with their operators and manpower.
- Cyclone will most likely have varying levels of impact across the states; therefore, the respective state power utilities **should contact their neighboring state utilities** to make preliminary arrangements in case of emergency requirement of manpower or material for restoration activities.
- **Suspension of casual leaves** sanctioned earlier for all power sector employees (states can take their calls based on expected impact; exemptions in high impacted areas to be only on a case-to-case basis).
- Immediate deployment of field teams to identify and clear any **trees and vegetation** that may cause damage to critical power lines or other power infrastructure.

Communication

- **Create a webpage/microsite/section conspicuously** on the existing website of the energy department/ power generation companies, for sharing regular updates for power users on location-wise nodal officers and key contacts, safety measures to be undertaken, updates on power outages in the solar plant, power restoration activities, and timelines (if required).
  - Spread awareness and advisory on safety norms to be followed specifically about electricity use for all consumers
  - Hold emergency meetings with critical large consumers on potential load-shedding and grid-balancing activities that may be needed, and possible support and impact on them.
- Create a **central war room**, where the overall monitoring and control of activities like grid supply status, damage to infrastructure, response, and restoration coordination will be undertaken. This should also coordinate and seek regular updates from the IMD and the state disaster management authority on the status of the cyclone.
- Formation of **core teams across Generation, Transmission, and Distribution** utilities in the state, each exclusively looking into the following:
  - Material procurement and management,
  - Manpower arrangement & Deployment
  - Logistics/Transportation, Lodging and Boarding, etc.
  - Collection of field Information and MIS preparation/reporting
  - Coordination with field offices through messengers

2. During the cyclone's impact

- During the impact period, the following activities may be undertaken in a coordinated manner to ensure network safety: (1) Temporarily switch off 33 kV feeders experiencing very high wind speeds (say 50 mph); (2) Immediate shutdown of 11/33 kV feeders with reported damage to OH conductors, pole damaged/ uprooted; (3) The SRLDC and WRLDC to be in constant touch with SLDCs of relevant states and take corrective measures to ensure overall continuity of the GRID.
- Regularly update the existing company website on the outage scenarios, and **messages/emails to power users** on their registered contact details regarding power outages.
- Central war room to be in touch with:
  - **MET/DM state disaster management department** for updates on the evolving path of a cyclone.
  - District / Local offices in the area of the potential impact

3. Near-term restoration and reconstruction activities

Damage assessment

- Adopt a two-phased approach to **assess the damage**, the first being a **quick high-level assessment**, which may be carried out by personnel on bikes, communication from emergency teams at the field, etc., for determining damage to power infrastructure leading to disruption in supply to critical institutions like hospitals, water supply utilities, telecommunication, state government department offices, railway stations, airports, etc. The second one can be a **detailed assessment** to assess the detailed impact to carry out extensive reconstruction activities.
- Communication with the state government on **estimated damage** and immediate support and **fund requirements** for restoration and reconstruction activities.

System response and restoration activities

- Develop operating procedures to ensure the quality of work during reconstruction, especially during erection and commissioning, is not compromised to meet aggressive restoration timelines.
- **Safety officers** must be designated across the impacted areas (if any), who is to ensure no untoward incidents occur during response and restoration activities, like back feed current in conductors, handling broken conductors, switching on the repaired 11/33 kV feeders, responding to flooded areas.
- After the passage of the cyclone, if a larger section of the T&D network needs a **black start**, the switching of the sub-sections of the system may be done in coordination with the SLDC to ensure minimum disturbance to the power grid at large.
- In case of any **severe damage to bulky equipment** like power transformers in switch yards, the concerned power utility should ensure replacement (if required) in minimum time. In case the bulky equipment is at a distant place, the utility shall seek state government support to ensure logistics.
- Local district administrations **(Police/DM/Collectors)** may be contacted for help in advance to avoid any law-and-order situation during restoration/reconstruction activities.
- **Mobilization advances** may be given to contractors involved in restoration and reconstruction activities, to primarily meet the petty expenses and also to pay the workers/laborers involved in restoration activities.
- **Performance based compensation** may be announced in advance to the contractors involved in restoration activities, E.g. a one-time unique incentive of say 15-20% of the bill amount for works done within 1st week and 10-15% for works done within 2nd week, etc.

N O T E S

Disclaimer: ***Please note that this is a general advisory and before implementing the recommendations proposed in the document, seek independent analysis, assessment, verification, and adequacy assessment from power sector practitioners/experts.***

CDRI

Coalition for Disaster Resilient Infrastructure

4 & 5 Floor, Bharatiya Kala Kendra,

1, Copernicus Marg, New Delhi 110001, India

info@cdri.world

www.cdri.world

@cdri_world

@cdri.world

@coalition-for-disaster-resilient-infrastructure