Post-Earthquake Mitigation of Electricity Power Systems, a Case of Siliguri

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Abstract: - Earthquakes are a common phenomenon in the Indian subcontinent. The catastrophe is severe in the epicenter of the earthquake, but adjacent areas may also suffer. It further leads to a post-disaster crisis since the earthquakes severely compromise the physical and social infrastructure of the affected area. Power outages are frequently observed during and after significant earthquakes. The duration of the outage in any area is significantly influenced by disruptions to the electric power lines that serve the area. This research targets to study the impact of earthquakes on the electricity-based power systems of Siliguri, West Bengal, India. Critical appraisal of disaster management plans has been conducted to develop an operational contingency plan for adequate power outage management in disaster-prone zones of the case area. A substitute distribution layout is provided in the post-disaster timeline to cater to the electricity needs in less affected zones immediately. The paper further discusses some strategies and policy recommendations to combat the infrastructural challenges generally caused by earthquakes.

Key Words: —*Disaster Prediction, Disaster mitigation, earthquake contingency, Electricity restoration*.

I. INTRODUCTION

Electricity is the backbone of modern society. It is essential since the critical infrastructure systems are dependent on the electric power supply. This sector's framework regulates the energy supply and further channelizes the policies. Natural hazards can disturb the electricity supply through power outages, which can lead to accidents. It brings economic activity to a halt and hinders emergency response until electricity supply is restored to critical services. This study aims to elucidate the influence of earthquake occurrence on the power grid recovery time. For this purpose, impact-based analysis of the power grid performance during earthquakes was institutional to this research.

Natural hazards like earthquakes affect the physical infrastructure in different ways. Earthquakes cause damage to heavy equipment (such as generators and transformers), ground failure, and soil liquefaction, which can be devastating to electric infrastructure assets.

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Electric systems are particularly vulnerable to seismic forces and suffer extensive damage in earthquakes. Since we cannot avoid them, adequate mitigation strategies can lead to effective restoration at affected sites. Equipment anchoring at stable locations can arguably reduce the exposure to ground failure. Recovery time is sensitive to external factors driven by the balance of in-situ repairs and capabilities. However, the immediate recovery may be time-consuming due to inadequate access to damaged facilities, landslides, congestion, and disaster debris. Based on a literature study, it is identified that the time to restore power supply ranges from a few hours to months in case of severe damages, but more frequently from 1 to 4 days in case of minor / fewer damages. Microclimate and weather conditions at the site affect transmission and distribution equipment through geomagnetically induced currents (GICs), which can potentially impact the entire transmission network that can severely damage the infrastructure establishments of the site.

According to existing case studies, geomagnetic storms can cause abnormal operation or equipment damage significantly. However, early warning and predictions can help to manage the post-disaster outcomes. Efficient disaster forecasting can provide transmission system operators the necessary information to prepare for a disaster. System-wide incorporations are the driving forces of recovery time post-earthquake. When damage is limited to minor alterations like wire tripping of appliances, restoration time is less than 24 hours. However, significant repairs of damaged equipment may take up to several months. In disaster preparedness, factors affecting the power grid recovery time in the aftermath of an earthquake include disaster resilience of utilities and recovery potential of critical infrastructure (mainly transportation and telecommunications). Hence, resilience is critical to disaster management.

II. Impact Of Earthquake On The Electric Power System

Earthquakes damage the power generation, transmission, and distribution subsystems by compromising the structural integrity of the ground. The equipment failure results in severe structural damages. Earthquakes cause different types of disruptions to electricity networks. Natural events may not generate system failures. They can cause significant damage to the underlying systems at multiple levels, which may further lead to prolonged recovery and restoration. This paper outlines the type of damage incurred to power grid components due to earthquakes by identifying the extent of damage that affects the post-recovery time. Ground deformation, settlement deterioration, soil liquefaction, lateral spread are expected outcomes in the advent of earthquakes that cause severe damage to buildings, large transformers, and other heavy equipment. Soil liquefaction not only affects the buried cables but also significantly causes foundation failure of transmission towers. Simultaneously, earthquakes severely damage transportation networks and nodal hubs like ports, airports, railway stations, metros, bus terminals, etc. Road networks, Highways, railroad bridges are most vulnerable since they can hinder the transport infrastructure permanently. Seismic forces can cause structural damage to Telecommunication. Most common damages include disrupted mobile network cell towers and two-way radio repeaters. Electricity supply companies rely on two-way radios and cellular telephones to coordinate repair and maintenance crews in daily and emergency operations. These disruptions practically bring urban areas to a standstill. The disruption of telecommunications poses a severe crisis to the emergency services than any other critical infrastructure sector. Lack of communication, damages to transport networks, delay in emergency response can affect immediate mitigation strategies in the affected site. Hence, there is a need to address these criteria to reduce delays in recovery time for further restoration of activities post the disaster.

III. Study Area Profile

Siliguri is located at 26.71°N and 88.43°E in the Himalayan foothills. It is often regarded as the gateway to North-East India. It is vital to the state of West Bengal since it is the third-largest urban agglomeration after Kolkata and Asansol. It is the headquarters of the plains sub-division of Darjeeling District of West Bengal and is situated 392 feet above mean sea level on the river Mahananda. According to the CDP Report of Siliguri, it is located in proximity of three international borders (Bangladesh, China, and Nepal). The connectivity of Siliguri from Kolkata is by NH-31. It has three railway stations, namely, Siliguri town, Siliguri Junction and New Jalpaiguri. The Bagdogra International Airport, situated about 15 km away, is the only airport in the region. According to Census 2011, the city's population was 5.13 lakhs. Out of 47 wards, 14 wards fall in the Jalpaiguri district, and the remaining 33 wards in the Darjeeling district. The population density of the city is 11,274 persons per sq. km. The literacy rate of the Siliguri urban area stands at 79% and the sex ratio at 946. As per population growth trends and future economic growth projections, Siliguri's population would increase from 5.1 lakh in 2011 to 9.12 lakhs by 2031 and 11.31 lakh by 2041.

IV. Discussion

Siliguri faces earthquakes almost every three months. Two quakes of magnitude 3.0+ have been faced recently in May 2021, the largest being a 3.8 event. Hence, it is detrimental to provide strategic, operational contingencies to combat the disastrous outcomes. The following is a discussion of crucial mitigation strategies by identifying the type and severity of damage to buildings, equipment, transmission, and distribution lines in Siliguri. In this research, we critically analyzed the electric power infrastructure in the case area through secondary sources of information. Buildings in electric power networks comprise control rooms, heavy equipment, turbines, and transformers. Most buildings identified in this study were structural sound. They were of reinforced concrete frame, masonry (reinforced or unreinforced), or mobile structures. These buildings were not significantly high (between one to three stories), which is advantageous to their seismic performance. Multi-story buildings do not have a beneficial seismic performance, primarily if heavy equipment is located on the upper floors. However, Electricity utility buildings have performed exceptionally well in the past five earthquakes in the study area. According to the Comprehensive development plan of Siliguri, there are 39 existing facilities comprising substations and power plants. These facilities were subjected to peak ground accelerations (PGA) between 0.15g and 0.97g. It was highlighted that, out of all the facilities, we noted severe or catastrophic structural damage to buildings only in five of the cases. In two cases, PGA was 0.69g and above. Building damage was caused by ground failure (landslide, liquefaction, slope failure) in the other cases. Thus, ground anchoring is identified to be a crucial mitigation strategy for faster recovery. Catastrophic structural damage may increase recovery time as restoring the critical equipment existing in the vicinity of the affected buildings is a time-consuming process. In addition, debris from collapsed buildings may damage adjacent equipment. They also pose severe health risks for the emergency response teams and those stuck in the debris. Hence, we should not compromise the structural integrity of buildings to prevent delays in recovery. Emergency Batteries that provide power to protective equipment are especially vulnerable to this type of failure. They are crucial for backup power provisions to protective equipment, control centers, and telecommunication systems in post-earthquake hours. However, unanchored batteries may slide and topple, while anchored batteries generally remain undamaged. Large Power Transformers (LPTs) are often extensively damaged from inertial seismic loading. Depending on the ground motion intensity, the damage to massive equipment from rocking may range from slight to catastrophic.

The slightest form of damage is identified to be tripping of equipment protection devices because of seismic vibration. These are generally reset and re-energized within less than 24 hours after the earthquake in case of minor alterations due to earthquakes. Most evidently, strong tremors can lead to equipment failures in case of a faulty foundation. LPTs, Emergency Diesel Generators (EDGs), turbines may break off from their foundations and tilt, topple or move horizontally. Tilting or toppling can cause the transformer oil to drain/leak. The earthquake load distribution is in proportion to the relative strength offered by the resisting members. Therefore, systematic anchoring and strong isolation of the base are successful mitigation options.

In the next segment, we critically analyzed telecommunication services in this study. In the previously recorded seismic activities of the last five instances, numerous reports have identified mobile tower disruptions, two-way radio disruptions, lack of cell network due to lack of battery power during prolonged power outages, backup generators failing to start due to lacking fuel. The resulting loss of two-way communications between a power utility and its repair crew is an important parameter that determines the power grid recovery time. These are most critical for the post-disaster emergency teams to cater to the immediate needs of the people. Modern emergency systems use two-way radios and mobile phones intensively, especially in the emergency response stage. When both run out of power, rescue teams, ambulance, police, and other agencies fall back to their redundant systems. Thus, in these circumstances, local radio stations, satellite communication, landline connection can only prove helpful in receiving disaster-related information and updates.

At the power generation, transmission, and distribution levels, some key deliverables have been identified that can be efficiently administered in the case area. In case of minor damages to supply lines, we can reroute power by switching to a backup configuration. In case of significant damage, few critical nodes can be repaired, and the electricity supply may be restored. Furthermore, spare equipment and materials can be used to repair some damages, which is economical and timesaving. Distribution Systems Operators (DSOs) stockpile equipment to handle extensive repairs, while additional items are available on order.

V. POLICY RECOMMENDATIONS

From the policy perspective, the idea is to come up with efficient policy interventions, which target the safety and security of Siliguri's electricity supply. Administrative Jurisdiction over adequate disaster management for the power supply exists at various levels. The electricity supply chain derivative is recognized by public and private stakeholders, which have authority over post-disaster management.

Policy-level recommendations should be aligned to achieve disaster resilience at the core system infrastructure level. Energy-related regulations focus on maintaining a balance between demand and supply. Civil protection regulations require States to produce comprehensive state disaster management strategies.

However, it does not specify how we can utilize critical infrastructure to mitigate earthquake risks. Critical infrastructure policies are focused on contingency Plans, which target power grid resilience by identifying various threat scenarios. Without a proper understanding of disaster resilience, critical infrastructure plans may not target the necessary response measures.

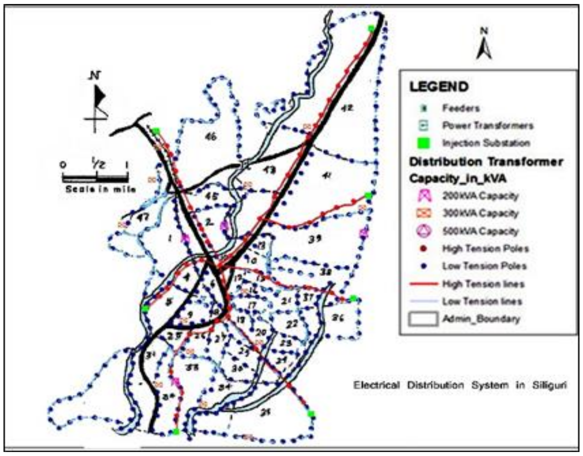

Fig.1. Electricity distribution layout of Siliguri

A. Consistency in Scenario Development

Whenever possible, administrative bodies in the city should conduct risk assessments concerning a probable set of alternate scenarios. Here, policies should target strategic needs for adequate risk management. The state has used a consistent set of scenarios to conduct both the National Risk Assessment under the National Disaster Management Authority (NDMA) Decision and the identification of critical infrastructure under the Siliguri Critical Infrastructure Directive. We could amend the proposed recommendation on risk-preparedness in the electricity sector to include a similar requirement. Critical infrastructure protection agencies could consider requiring identified National Critical Infrastructure Operators to include at least the scenarios identified in the National Risk Assessment.

B. Integration of Risk Management Activities among Departments

Risk management efforts should be integrated to maximize efficiency. Using the same set of scenarios across all risk assessments can provide a joint base for integrating risk management efforts and making the best of each policy area. For example, a city corporation or State Risk Assessment may identify an earthquake scenario. Based on this scenario, the National Disaster Management Authority (NDMA) of this State may develop a hazard mitigation strategy, eventually supported by an action plan to develop its Operator Security Plan. The OSP will likely describe the impact of that scenario on the security of electricity supply in further detail compared to the city corporation. The measures stipulated in the OSP should be integrated with the national risk mitigation strategy to maximize the benefit/cost ratio of the interventions and reduce the risk stemming from prolonged power outages to a minimum. In addition, interoperability among different departments will lead to better disaster management with adequate disposal of resources.

C. Integration of Risk Management Activities among Departments

Risk management efforts should be integrated at all levels of jurisdiction to get the best performances. For example, a city municipal corporation or State disaster assessment may identify the likelihood of an earthquake scenario. Based on this scenario, the State Disaster Management Authority (SDMA) may develop a hazard mitigation strategy through early warning mechanisms and pre disaster forecasting technologies. Further, they may develop an operation contingency plan (OCP). The OCP will likely describe the impact of that scenario on the electricity supply lines in further detail. The measures stipulated in the OCP can be aligned with the national risk mitigation strategy, to maximize the benefit/cost ratio of the interventions and reduce the risk stemming from prolonged power outages to a minimum. In addition, interoperability among different departments will lead to better mitigation with adequate disposal of resources.

D. Building Resilience into the Grid

Traditional hazard mitigation strategies have focused on strengthening the power grid components, such as equipment and buildings, based on the expected level of risk. Building resilience into the grid recommends system operations to continue performing their required functions when critical parts of the system are taken out of service and promptly return to normal operations after a disruption. Resilience requires a change in design to allow the grid to be reconfigured in response to various threats and enhance maintenance speed. An assessment of how long the microgrid will be expected to operate independently is necessary. In addition, use of smart grid technologies will allow power grid operators to automate the process of detecting an outage and reconfiguring the grid to reroute power to the affected area through available circuits. Spreading the investment over several fiscal years may be a feasible way to finance the design change. Despite the attractiveness of the idea, however, its implementation will require extensive operational and regulatory changes.

E. Development and Implementation of Emergency Operations Plans by NDMA.

The findings of this study have consistently demonstrated the need for System Operators to develop, implement and exercise comprehensive outage management plans before disaster strikes. These emergency plans should describe emergency repair and recovery actions, assign responsibilities, identify resources, and address coordination and communication. They should also establish emergency response, including on-call arrangements of qualified personnel available to respond to natural disasters or other incidents.

F. Stockpile Spare Items for Repairing Key Assets and Equipment

The availability of parts and equipment for critical assets and facilities is essential for a faster recovery. Electric utility companies maintain a stock of spare items to handle daily repairs and minor emergencies. Extending these stocks to cover natural disasters.

G. Prioritize Repairs to Critical Teams

OCPs should identify critical teams ideally during the development of operation contingency plans. The latter should include critical resources and locations where It can provide the critical assets immediately. The recommendation should consider the potential consequences of the electricity disruption and the minimum power required to maintain functionality. Planning these aspects before an earthquake can highlight emergency services' priority-based response during the recovery phase.

VI. CONCLUSION

The study determines to establish a qualitative strategy-based initiative for post-earthquake mitigation for electric power systems. The research can further establish the critical conceptual framework that can be undertaken for efficient earthquake mitigation at all levels with suitable policy interventions. Further, the research can explore the dimensions of intelligent energy systems, disaster resilience, and management.

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