1. Introduction

The world is being subject to climate change and Mauritius Island has experienced a flash flood in March 2013. Operational risks for the electricity sector due to equipment failure have traditionally been linked to loss of revenue for the country as a result of the economic activities reliant on electricity being disrupted and loss of revenue for the utility as a result of the utility being unable to supply electricity to consumer willing to consume. With increasing risks of natural catastrophes, it is required to extend the analysis of operational risks to include the human safety and property safeguard aspects during natural catastrophes. This paper aims to review the operational risks and risk mitigation strategies put in place including those that may arise from adverse climatic conditions such as flash floods for the electricity sector in Mauritius.

2. An Overview of the Power System in Mauritius

The electricity or power sector in Mauritius mainly involves centralized power generation, power transmission at high voltage from the power plants to bulk supply points located close to the load centres and power distribution at medium voltage and low voltage. There are primarily five voltage levels in Mauritius: 6.6kV or 11kV for power generation, 66kV for power transmission, 22 kV or 6.6kV for medium-voltage distribution and 400V for low-voltage distribution with voltage transformation taking place at the level of the bulk supply points and MV/LV distribution transformers as illustrated in Figure 1.

The Central Electricity Board (CEB), as a vertically-integrated organization, is involved in electricity generation, transmission and distribution with the Independent Power Producers (IPPs) also involved in electricity generation. A reliable electricity supply is a pre-requirement to support the economic growth given that electricity is an input to various economic activities and to enhance the standard of living of the population. As reliable and continuous electricity supply during adverse meteorological conditions such as flash floods can help to bring human life to safety and to safeguard property, the CEB is entrusted with the responsibility to properly plan the expansion, design, install, maintain, and operate electrical facilities to ensure reliability and security of electricity supply in Mauritius.

3. Review of the Risks faced by an Electricity Utility such as the CEB

The setting up and operation of facilities for power generation, transmission and distribution is capital-intensive, in particular for an insular island like Mauritius, which needs to import most of the equipment and fuel requirements. As a result of the extensiveness of its operation in electricity generation, transmission and distribution, the CEB is subject to different risks as outlined below and illustrated in Figure 2:

- Market risk: Risk of financial gain or loss due to exposure to fluctuations in market prices. In particular, interest rate risk (change in interest rate), currency risk (change in foreign exchange rate) and commodity risk (change in commodity prices) affects the electricity utility.
Figure 1: Overview of the power system in Mauritius

Operational Risk

CEB as an electricity utility involved in generation, transmission and distribution of electricity

Credit Risk

Business Risk

Market Risk
• Credit risk: Risk of loss due to a counterparty defaulting on a contract or due to uncertainty about a counterparty’s ability or willingness to meet its obligations.

• Operational risk: Actual or potential losses resulting from events caused by inadequate or failed processes, people, equipment or systems, or from external events.

• Business risk: Risk inherent to the electricity or power industry such as uncertainty in demand and change to laws and regulations.

The next sections shall focus on the operational risks faced by the CEB and the strategies put in place to mitigate these risks. Operational risks mainly include 1) loss of revenue to the country due to disruption in electricity supply 2) the loss of revenue to the CEB from the loss of sales due to the inability of the CEB to supply electricity to customers that are willing to consume and 3) damage to electrical equipment due to adverse meteorological conditions and leading to disruption of electricity supply. In the context of natural catastrophes such as flash floods, maintaining continuous electricity supply to aid in bringing human life to safety and safeguarding property is of prime importance.

4. Operational Risks and the Need for Trade-off between higher Reliability and Increase in Investment Cost

The electricity infrastructure (power system) is composed of physical assets (equipment) such as generator, transformer, transmission line, distribution line and switchgear that are subject to unavailability due to maintenance and following fault from operation or damage due to exposure to adverse climatic conditions. The adoption of the N-x contingency criterion provides for the electricity utility to be still in a position to supply the total system demand with x equipment out of service due to maintenance, fault or damage. The adherence to the N-x contingency criterion requires investment in spare generation, transmission and distribution capacities, which spare capacities are utilized in the event of equipment maintenance, fault or damage.

Electricity utilities worldwide adopt different contingency planning criterion across the generation, transmission, medium-voltage distribution and low-voltage distribution systems taking into consideration the number of customers affected by an outage, associated loss of electricity sales revenue and expected time to repair and restore the system. As one moves from the generation through the transmission through the medium-voltage distribution system to the low-voltage distribution system, the number of customers affected by an outage decreases and so does the effort required to repair and restore the system. It is emphasized that providing for spare equipment capacity to increase reliability and security of electricity supply require additional financial resources such that a trade-off is required between higher reliability and associated increase in investment cost.

5. Managing Operational Risks in the Electricity Sector through Planning and Design Standards

In this section, the planning and design standards adopted for the generation, transmission and distribution systems as illustrated in Figure 3 are reviewed in relation to the ability of the power system to continue to operate following an equipment failure or during a natural catastrophe such as flash floods.

5.1 Generation system

The N-2 criterion is adopted for the generation system, which requires that the CEB be still in a position to supply the maximum system demand even if the two largest generating units are not available due to maintenance or breakdown. In addition, power plants are designed to withstand the cyclonic conditions prevalent in Mauritius and equipped with proper drainage system for water evacuation in the event of flash floods. Therefore, it shall be still possible to generate power to meet the prevailing load demand given that two generating units are not available and under the adverse climatic conditions mentioned above.
5.2 Transmission system

The N-1 criterion is adopted for the transmission system, which requires that the CEB be still in a position to transmit power to all bulk supply points and load centres even if one transmission line or power transformer at a bulk supply point is out of service due to maintenance, fault or damage. This is achieved by providing for spare transmission line capacity and spare power transformer capacity at the bulk supply points (HV/MV substations). In addition, the transmission lines, towers and switchgears are designed to withstand the cyclonic conditions prevalent in Mauritius. The bulk supply points are equipped with proper drainage system for water evacuation in the event of flash floods. Therefore, it shall be still possible to transmit power to meet the prevailing load demand given that one transmission line or power transformer is not available and under the adverse climatic conditions mentioned above.

5.3 Distribution system

The medium-voltage and low-voltage distribution networks are made up of a mix of underground and overhead reticulation with the underground option being more expensive and primarily used in densely populated areas where it is difficult to satisfy the minimum clearance condition required for overhead lines and where there is a higher probability of damage to overhead lines due to accidental contact or collision.

Outage on a medium-voltage distribution feeder may affect up to several MWs of served load demand, which makes it important to provide alternative or back-up supply at the medium-voltage level. This is achieved by limiting the loading of a medium-voltage distribution feeder to 50% of its rated current-carrying capacity under normal condition such that it can take up the total load on an adjacent medium-voltage distribution feeder in the event of outage on the supply side of that feeder. Therefore, it shall be still possible to distribute power at the medium-voltage level given failure of a medium-voltage equipment at the bulk supply point (HV/MV substation).

Compared to the medium-voltage distribution feeder, the load supplied by a distribution transformer and its outgoing low-voltage feeders is significantly less and system repair and restoration is expected to be easier and faster. It is therefore not recommended for the electricity utility to provide redundancy and back-up supply at the level of the distribution transformer and the low-voltage network. In this line, customers such as hospitals and high-rise buildings that have critical operations and emergency loads are advised to have a stand-by generating set to cater for their
emergency loads in the event that the electricity supply from the CEB is not available as illustrated in the schematic diagram of Figure 4.

In the context of flash floods, buildings need to be equipped with proper drainage system and for those having a basement, water pumps become a necessity to aid in water evacuation. As important, the pumps and emergency loads need to be supplied with continuous electricity supply during flash floods. Given that electrical equipments such as transformers, switchgears and standby generator set cannot withstand contact with and submersion in water, it is advisable to locate these where the probability of getting in contact with water is low. In this line, these should be located on the ground floor and all effort made not to have them in the basement. This shall ensure continuous electricity supply to the essential loads such as emergency lights, access doors, water pumps and lifts, which shall help people in the building to move around and reach safety during flash floods. This shall also safeguard the electrical equipments from damage and loss due to contact with water.

6. Conclusion

The above review indicates that the risk mitigation strategies put in place by the CEB as the national electricity utility are sufficient to safeguard its power system and ensure its continuous operation and electricity supply given equipment outage and during adverse meteorological conditions such as flash floods. Risk mitigation is a continuing activity and requires the continuous identification of additional risks alongside with the monitoring and assessment of the current planning and design standards for risk mitigation.

Reference

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