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Public Utility Commissions to Foster Resilience Investment in Power Grid Infrastructure

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Abstract

In the United States, power system works at 99.9 percent reliability but it does not imply that it is safe and reliable against all types of hazards whether natural, technological or man-made. Especially the high impact low probability (HILP) events also called "black-swan events" offer a complex risk environment for power grid infrastructure. On the other hand, the utility companies have to work in a very competitive and regulated environment maintaining a balance between their investments on infrastructure, rate of returns, serviceability and cost to the customers. Hence, it is not economically feasible and justifiable to harden the entire infrastructure owing to budget constraint and regulatory issues. In such a scenario, enhancing resilience selectively within the power grid infrastructure would serve the purpose of achieving optimum security against any type of hazards, including HILP events. Resilience is the property that incorporates robustness and rapid recovery of infrastructure in face of any type of unprecedented havoc hazards. Enhancing resilience is cost intensive and future return on such investments are also risky and uncertain. Again, "resilience investments" i.e. investments needed to enhance resilience of power grid need approval from Public Utility Commissions (PUC) for cost recovery from public consumers and also must involve other investment agencies to invest in the power infrastructure by offering them good rates of return on investment (ROI). This paper will discuss the various key issues that hinder adequate investments in resilience enhancement of power grid infrastructure. Some of the key issues identified are (i) lack of knowledge about the Black Swan Events and their impact on the power grid infrastructure; (ii) strict regulatory restrictions imposed by PUC within the purview of which the utilities work; (iii) lack of strong value proposition for resilience investment business cases as presented by the utilities to the PUC, and (iv) lack of adequate incentives for the investors to invest in the power infrastructure. A conceptual strategic decision making framework for the PUC is also proposed that would help in approving or incentivizing adequate resilience investments for power grid infrastructure.

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1. Introduction

Power Grid Infrastructure (PGI) is the cornerstone of our society. It is one of the most important of the lifeline infrastructures that is expected to provide services even if the other infrastructures fail [1], [2] . The continuity in electricity services is an absolute necessity because without electricity, all the essential services of the society such as continuous business and government operations, public health and safety, and national and economic safety will be disrupted leading to extensive economic loss. In the United States, although the power system works at 99.9 percent reliability, it does not imply that the power infrastructure is safe against all types of hazards whether natural, technological or man-made. Especially the *high impact, low probability (HILP)* events offers a very complex risk environment for the infrastructure [3].

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The HILP events which are also known as "*Black Swan Events"* are considered to be the instigating events that could cause cascading failure of the power infrastructure and consequent disruption in the electric services to such an extent that the restoration of services back to ex-ante disaster condition might take weeks, months or sometimes even years [4]. Co-ordinated physical or cyber-attacks and geomagnetic disturbances are a few examples of such HILP events when the PGI is considered.

In addition to these external threats, there is a growing internal weakness within the PGI systems caused by several factors that further renders vulnerability to the entire system when exposed to such external threats. Examples of some of these factors include aging of the PGI and the increased interdependency of all the other critical infrastructure sectors on the power sector. The increased interdependency introduces fragility to the network structure of PGI [5]. In addition, owing to the climate change, there is an increased frequency of natural disasters which disrupt the power generation and delivery in many instances and thus weaken the power delivery service. For example, increased droughts reduces power generation from the steam power plants leading to scarcity of power; the storms, hurricanes and tornadoes, on the other hand, physically disrupts the power transmission and distribution systems.

Under such circumstances, it is extremely important to protect the national grid and enhance its security in face of the Black Swan Events. Fortunately, electricity service providers understand the importance of reliability of the power system and its need for proper functioning of the society and economy and they take every initiative to maintain/improve reliability of the grid. The North American Electric Reliability Corporation (NERC) defines operating reliability as "*the ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system components*" and it defines adequate reliability as "*the ability of the electric system to supply the aggregate electric power and energy requirements of the electricity consumers at all times, taking into account scheduled and reasonably expected unscheduled outages of system components*" [6]. It is noteworthy here, that the "reliability" property of the electric system is not capable of assessing the unscheduled and extraordinary unexpected outage risks and thus this property alone is not able to enhance the security of the grid against the Black Swan Events. The reason being these types of events create extra-ordinary hazardous risk scenarios that would cause extensive infrastructure damage and service disruptions — the estimated extent of damage and disruption being much higher than the combined effect of the most severe recent disasters, Superstorm Sandy and Hurricane Katrina in the US [7].

In this context, the "resilience" of infrastructure seems to play an immense important role. Resilience is the property that enhances security of any infrastructure and incorporates robustness and and helps in rapid recovery of infrastructure in the face of any type of unprecedented havoc hazards. However, enhancing resilience is cost intensive and the future return on such investments are also risky and uncertain. Again, "resilience investments" i.e. investments needed to enhance resilience of power grid need approval from Public Utility Commissions (PUCs) for cost recovery from the electricity consumers and also need good rates of return on their investment (ROI). This paper will discuss the various key issues that hinder adequate investments in resilience enhancement of PGI and will establish the need that the PUCs must foster the resilience investments as proposed by the utilities. Finally this paper presents a framework which will help in the decision making process of the PUCs in approving or incentivizing adequate resilience investments for PGI.

Nomenclature

PGI Power Grid Infrastructure
PUC Public Utility Commission