Power Blackouts

A Fluster Issue of Pakistan

Policy Brief

This policy brief provides an overview of the power sector in Pakistan while focusing on the issue of power blackouts and their impact on the country's economy. The purpose is to highlight the urgent need for attention and action in addressing the energy security challenges faced by Pakistan, emphasizing the importance of investment, governance, and policy measures to ensure a reliable and secure power supply. The brief also reviews mitigation strategies and emphasizes the significance of proactive measures, sustainable policies, and prioritizing the reliability of the power sector to mitigate the economic impact of power cuts.

Executive Summary

Power blackouts have become a significant issue in Pakistan, affecting the country's economy and daily life. The latest blackout on January 23, 2023, affected nearly the entire country, with an estimated financial cost of Rs100 billion. While this was not the first instance of a massive blackout in the past three years, it highlights the need for urgent attention to the energy security of the country.

Power blackouts occur when there is an imbalance between power generation and consumption, leading to a complete loss of power in a geographic area. These blackouts can have severe economic consequences, including decreased economic activity, reduced revenue for businesses, and higher expenses for households and companies. The industrial sector, heavily reliant on electricity, is particularly vulnerable to power cuts, negatively impacting the country's GDP.

Power blackouts in Pakistan are caused by a combination of factors including faults in the power grid, high demand for electricity, equipment failures, natural disasters, cyber-attacks, human error, and infrastructure attacks. These factors can trigger cascading effects that lead to a widespread power failure.

Addressing power breakdowns in Pakistan requires a comprehensive policy response that considers technical, operational, and policy-related factors. Adequate investment in the power sector, improved governance, regulatory oversight, and tariff adjustments are essential for ensuring a reliable and secure power supply. Power blackouts result in significant financial losses including lost production, idle labor and facilities, damaged equipment and products, and increased expenses for households and businesses. The exact financial impact is challenging to estimate, but indirect costs can exceed direct costs by up to five times.

Mitigation strategies from a global perspective include upgrading infrastructure, adopting grid modernization technologies, and implementing design standards that consider environmental conditions and known threats. To mitigate the risk of power blackouts, Pakistan needs to invest in a highly secure and technologically advanced power monitoring and control system to prevent cyber-attacks. Clear frameworks for governance and collaboration among stakeholders, including public and private utilities, system operators, insurers, and consumers, are necessary to enhance the resilience of power grids.

Power blackouts pose a significant risk to Pakistan's energy security and economy. Taking proactive

measures, implementing sustainable policies, and prioritizing the reliability of the power sector is crucial for ensuring a reliable supply of electricity and mitigating the economic impact of power blackouts.

Introduction

Energy is a crucial requirement for the smooth functioning of various sectors such as industries, agriculture, education, healthcare, and business activities. It plays a central role in boosting economies, and progress cannot be achieved without adequate energy resources. However, in Pakistan, ensuring energy security has become a complex issue that needs to be promptly addressed. On the morning of January 23, 2023, due to an instance of tripping in the national grid, the whole country experienced a blackout for which the financial cost is foreseen as Rs100 billion.[1] This was not a new compromise on energy security rather it was the second massive blackout the country has faced in the last three years.

A blackout occurs when there is an imbalance between power generation and consumption, resulting in a complete loss of power in a geographic area. It is the most severe form of power outage. To prevent a blackout, it is necessary to implement selective power cuts for a controlled shutdown of the power supply in the area where the fault has occurred. Faults in the power grid can lead to cascading effects that can spread to other nodes in the grid due to power stability and transient constraints.[2] The process of restoring power after a blackout is often a complex task that requires utilities and power stations to address the root cause of the outage. The time it takes to make repairs can vary greatly depending on the configuration of the affected electrical network.[3]

Power blackouts have caused substantial financial losses to Pakistan over the years. These losses can be linked to various factors, such as decreased economic activity, reduced revenue for businesses, and higher expenses for households and companies. The most significant impact of power blackouts is the reduction in economic activity. When power outages happen, many businesses are compelled to shut down or operate at a limited capacity, resulting in decreased productivity and revenue. The industrial sector, which relies heavily on electricity, is especially susceptible to blackouts, which can negatively affect the country's GDP.

Power blackouts are usually caused by a combination of factors rather than a single event. No outage has been recorded where a flawless grid collapsed entirely due to a single cause. There are various reasons that can trigger a power system collapse, such as major faults, high grid utilization, high power demand, plant utilization, and defects due to material aging. With these primary reasons for faults that can occur in any grid connectivity, there is a high likelihood of a blackout.

In addition to these primary reasons, outages may also occur due to unforeseen simultaneous interruptions of several power plants, human error during switching operations, simultaneous grid interruption caused by tree contact, excavation work, balloons drifting into power lines, vehicles hitting utility poles, provisional shutdown due to electrical overloading risk, and sudden simultaneous high power demand, such as the usage of air conditioning during hot summers. Power line collapse or electrical equipment breakdown due to natural hazards such as wind, earthquake, snow or ice load, flood, lightning, space weather, and extreme temperatures can also cause blackouts. Insufficient communication between transmission/distribution system operators (TSO/DSO) and power suppliers and cyber-attacks on the power control systems can also lead to the intervention shutdown of units or devices.

Power System Stability and Cascade Effects

Cascading failure happens in systems where parts are connected, and if one part fails, it can cause other parts to fail too. This type of failure is common in power systems and computer networks. When a line in the power system fails, it can reduce the system's capacity, causing more stress on the remaining lines. If this stress is not relieved in time, more lines can fail, leading to a cascade failure. This cycle can cause a major blackout, where large areas of the network cannot supply power.

Breakdowns and Lack of Policy Orientation

Power breakdowns in Pakistan are majorly due to the lack of dedicated policy and market reforms to improve the power sector as outages are not only

[1] Salman Sidiqui, "Country incurs Rs100b loss due to power breakdown," *The Express Tribune*, January 24, 2023, https://tribune.com.pk/story/2397405/country-incurs-rs100b-loss-due-to-power-breakdown.

[2] Cascade effect in the power sector leads to the event when a single fault that has caused the tripping causes transients and disturbs the power stability, which in turn affects the whole grid dynamics.

[3] "The Many Causes of Power Failure," Generator Source, assessed on April 5, 2023, https://www.generatorsource.com/Causes_of_Power_Failures.aspx.

caused by technical or operational factors, but also by a range of policy-related issues such as inadequate investment in the sector, poor governance, inadequate regulatory oversight, and insufficient tariff adjustments. These issues have contributed to a lack of capacity in the power sector, insufficient fuel supply, and inadequate maintenance of power plants and transmission lines.

Moreover, policy decisions related to the allocation of resources, the selection of energy sources, the design of regulatory frameworks, and the management of public utilities have a significant impact on the power sector's performance. Therefore, addressing breakdowns in Pakistan requires a comprehensive policy response that takes into account not only technical and operational factors but also the broader policy context. It requires a long-term vision and commitment to implementing sustainable policies that can improve the power sector's performance, reduce costs, and increase access to electricity for all.

Economic Costs and Effects of Blackouts

Power blackouts have a huge impact on a country's economy as the timeframe incurred in the system shutdown has a significant cost. Pakistan has faced substantial financial losses from power cuts over the years. These losses can be attributed to several factors including reduced economic activity, loss of revenue for businesses, and increased expenses for households and businesses. One of the major impacts of outages is a reduction in economic activity. When power outages occur, many businesses are forced to shut down or operate at reduced capacity, which results in lost productivity and revenue. The industrial sector, which is heavily reliant on electricity, is particularly vulnerable to power blackouts, and the country's GDP can suffer as a result.

In addition to the economic impact, power blackouts also result in increased expenses for households and businesses. During blackouts, many people have to rely on backup generators or other forms of emergency power, which can be expensive to operate. On the generation side, post-blackout arrangements for system restoration require a high quantity of fuel to "cold start" a power plant.[4] The optimal time for the complete restoration of the power sector after an outage is about 24 hours, keeping in view the operation of the national grid. Moreover, during the restoration efforts, electricity remains unavailable, which on the supply side causes losses on account of the collapse of economic activity.

Direct costs of blackouts are lost production, idle labor and facilities, damage to electronic data, spoiled food and damaged products, damage to equipment, or customer refunds. Indirect costs can be looting, accidental injuries, legal costs, and loss of water supply. In general, indirect costs can exceed direct ones by up to five times. Power blackouts can have devastating economic impacts on many commercial entities and industries which are fed by the utility grid, i.e. hospitals, airports, cargo, textile industries, automobiles, cement, etc. However, it is difficult to estimate the exact financial losses a country faces from a power blackout.

Factors for Power Blackout/Breakdown

There are numerous factors, which cause power blackouts.

a. **Frequency drop:** The frequency of the national grid can drop due to a variety of reasons, including an imbalance between supply and demand, equipment failures, or issues with power generation or transmission. For instance, if there is a sudden increase in demand for electricity, the frequency of the grid may drop as power generators struggle to keep up. Conversely, if there is a sudden loss of power generation capacity, the frequency may drop as well. Additionally, frequency imbalance can also occur if there is a problem with the transmission lines or other equipment.

b. **Equipment failures:** If the power generators, transmission lines, or other equipment used to transmit electricity fail, it can cause a blackout.

c. **Overloading:** If the electricity demand exceeds the available supply, the power grid can become overloaded and cause a blackout.

d. **Natural disasters:** Extreme weather conditions such as storms, floods, and earthquakes can damage power infrastructure and cause outages.

e. **Cyber-attacks:** Cyber-attacks on power grid control systems can cause blackouts by causing power plants to shut down as modern energy networks are shifting to decentralized smart grids. Thus, greater emphasis on connectivity increases cybersecurity vulnerabilities.

[4] Cold start of a power plant refers to the mechanism where the plant is made operational after a total shutdown.

f. **Human error:** Human mistakes such as operator error, maintenance error or construction mistakes can also cause blackouts.

g. **Power grid failure:** Sometimes a failure in the power grid itself can cause a blackout, such as when a large portion of the grid becomes disconnected from the rest of the system.

h. **Extreme weather:** Strong winds take down trees that knock out transmission lines. Snow and rain may cause flooding which can damage substations and other infrastructure, not to mention making it difficult for engineers to fix.

i. **Large-scale accidents and system failures:** System errors such as software crashes, component faults, fires, and explosions and basic human error can cause failures.

j. **Infrastructure attacks:** Substations can be damaged by vandals or thieves trying to steal copper, while terrorists can target them using bombs or other physical weapons.

k. **Space weather:** Sun-based phenomena such as geomagnetic storms, solar flares, and meteors can have a devastating impact on satellites and electrical infrastructure.[5]

It is also worth noting that sometimes blackouts are planned in order to perform maintenance, upgrade equipment, or avoid a more severe failure.

Problem Mitigation: Examples from Global Perspective

Many countries in the world, including the USA, have faced numerous massive blackout events. To address these issues, countries have implemented various strategies and action plans. Some examples of efforts to mitigate blackouts around the world include:

- Following the 2000-2001 energy crisis in California, the state government created an Energy Action Plan that included increasing electricity output through new facilities, promoting conservation, and upgrading the grid infrastructure. The state also set conservation and efficiency standards for government buildings.
- After the 2011 blackout and subsequent problems with the San Onofre nuclear plant in the US, which caused it to shut down, electric companies reached deals with various institutions to voluntarily reduce energy use in case of emergency conditions. These agreements provide a way to reduce overall energy use in the system during emergencies without resorting to rolling blackouts. Participants receive reduced charges in exchange for their cooperation.
- Grid modernization technologies, such as smart meters, are also being introduced into power systems worldwide to handle severe blackouts. Smart meters provide more specific and real-time data than traditional meters, allowing electricity companies to charge more for energy during peak times, alert customers to those peak times, and quickly identify problems.

Besides, there are some other mitigation strategies to address these hazards, which include:

- Adoption of appropriate design standards, construction, maintenance, inspection, and operating practices are required. For example, a transmission line traversing high mountains must be designed for heavy ice loading, which may not be a design consideration for infrastructure located in desert environments.
- Design considerations for generation facilities, substations, transmission lines, and distribution lines should include environmental conditions such as extreme heat, cold, ice, and floods among other known threats. Utilities have less experience in design and hardening for uncommon threats such as geomagnetic disturbance or electromagnetic pulse. Nonetheless, these have been the focus of increasing attention and strategies to reduce system vulnerability.
- In principle, an infinite amount of money could be spent hardening and upgrading the system with costs passed on to ratepayers or taken from shareholder returns. However, utilities and their regulators are typically conservative in these investments.[6]
- Incorporating grid modernization technology into control centers to help manage the supply and

[5] "What Causes Electrical Blackouts?" Riello ups, assessed on April 5, 2023, https://www.riello-ups.co.uk/questions/ 26-what-causes-electrical-blackouts.

[6] National Academies of Sciences, Engineering, and Medicine, "Strategies to Prepare for and Mitigate Large-Area, Long-Duration Blackouts," in *Enhancing the Resilience of the Nation's Electricity System* (Washington, DC: The National Academies Press, 2017), 70-93, https://doi.org/10.17226/24836.

demand of electricity, to make it easier for smaller renewable energy inputs to be integrated into the system, and to increase the reliability and efficiency of the system.

These measures can have a high up-front cost but can save money over the long term by greatly increasing the efficiency of the electrical system. Efficiencies gained by grid modernization can also help to meet strict environmental requirements by reducing the need for energy resources.[7]

Figure 1: How to Cater to the Power Blackout Issue in Pakistan

Conclusion

The power blackout risk is generally underestimated. Long-lasting blackouts, including high economical losses, are not bearable for a country like Pakistan with its immense energy crisis and dwindling economy. Due to the increasing interconnectedness in combination with rather old infrastructure, it is expected that this risk may increase in both frequency and severity just as the blackout on January 23, 2023, affected almost the whole country (99% of the population). A rapid energy action plan in this regard is paramount.

A highly secure and technologically advanced power monitoring and control system is required to tackle cybercrime attacks. Although huge investment will be required, this can save the country from immense future economic loss due to power blackouts.

Policies must establish clear frameworks for the governance of power supply infrastructures. This is a necessary step to enhance the resilience of power grids. The main responsible stakeholders who have to take care of a reliable power supply are public and private utilities as well as system/network operators. All parties, insurers, electricity industry, and consumers should engage in risk dialogues to proactively address and manage related power blackout risks with the aim to maintain one of the most important goods in a civilized society – a reliable supply of electricity.

[7] "Case Study: California Blackouts," *National Geographic*, last updated October 22, 2022, https://education.nationalgeographic.org/resource/case-study-california-blackouts.

Appendix

History of Power Blackouts in Pakistan

Sr. No	Date	Population Affected (million) and Economic Cost	Reason	Details
1	Jan 23, 2023	230 (99%)[8] with the approximate losses of Rs100 billion	Frequency variation and voltage fluctuation	In winter, the demand for electricity lessens nationwide; hence, as an economic measure, temporary closure of power generation is the usual practice. Unfortunately, when the plant was turned on to meet the exceeding demand, frequency variation and voltage fluctuation were observed in southern Pakistan, somewhere between Dadu and Jamshoro. Subsequently, power generating units shut down one by one following the cascade effect.
2	Oct 13, 2022	200[9] with no financial loss estimated	Grid failure disruption in two 500 kV transmission lines	Sindh, Balochistan and some parts of Punjab remained without power for several hours after a grid failure shut down several power stations one by one in a stunning fashion. According to a statement issued by the Ministry of Energy (Power Division), the disruption occurred in two 500 kV transmission lines in the south of Karachi. The country had faced several breakdowns in the past and this one showed that the National Transmission & Despatch Company (NTDC) had failed to put in place permanent remedial measures to overcome the incidents in the future.
3	Jan 9, 2021	200 (90%)[10] with financial cost of over Rs120 billion	Engineering fault	Technical fault at one of Pakistan's biggest power plants sparked a massive grid breakdown, plunging the entire country into darkness. Seven employees of Guddu plant were suspended for negligence over the blackout, which lasted around 18 hours in most areas.
4	Jan 26, 2015	140 (80%)[11] with financial cost of Rs20 billion approximately.	Grid damaged by explosion in militant attack	The outage started after midnight when a transmission line connected to the national grid was damaged in an explosion. Authorities blamed the attack on a separatist group in Balochistan. The blowing up of two power pylons in Naseerabad created a backward surge, which affected the system.

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[8] Sophia Saifi, Azaz Syed and Rhea Mogul, "Nearly 220 million people in Pakistan without power after countrywide outage," CNN, January 23, 2023, https://edition.cnn.com/2023/01/22/asia/pakistan-power-outage-intl-hnk/ index.html.

[9] "Grid failure sets off huge power outage," *The Express Tribune*, October 13, 2022, https://tribune.com.pk/story/2381350/grid-failure-sets-off-huge-power-outage.

[10] Salman Masood, "Much of Pakistan Loses Power in Massive Blackout," *The New York Times*, January 9, 2021, https://www.nytimes.com/2021/01/09/world/asia/pakistan-blackout-power-failure.html.

[11] "Militant Attack Plunges Pakistan Into Darkness," Sky News, January 26, 2015, https://web.archive.org/web/20150619130351/http://news.sky.com/story/1414477/militant-attack-plunges-pakistan-into-darkness.