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Efficacy of Power Distribution Companies (PDCs): A Review of Selected Studies

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ABSTRACT: The electricity distribution sector plays a vital role in the modern economy, and the efficiency of power distribution companies (PDCs) has a significant impact on the cost of electricity and the reliability of the power supply. This paper reviews selected review papers on the efficacy of PDCs and identifies key factors that affect their performance. The review finds that the efficiency of PDCs is influenced by several factors, including the regulatory environment, the structure of the electricity market, and the technological capabilities of the companies. The paper also identifies several challenges faced by PDCs in improving their efficiency, such as the need to invest in new technologies and the need to manage the increasing electricity demand. The findings of this review can be used to inform policymakers and regulators in their efforts to improve the efficiency of PDCs and, in turn, the overall performance of the electricity distribution sector.
KEYWORDS: power distribution companies (PDCs), AT&C Losses, Power Sector Reform, KPIs.

I. INTRODUCTION

Power distribution companies (PDCs) play a critical role in the electricity sector, responsible for delivering electricity from transmission systems to end consumers. Their performance directly impacts the reliability, quality, and cost of electricity supply. Assessing the efficacy of PDCs is therefore essential for ensuring efficient and effective power distribution.This paper presents a comprehensive review of selected review papers on the efficacy of PDCs. The review aims to identify key performance indicators (KPIs) used to assess PDC efficacy, analyse the factors influencing PDC performance, and explore strategies for enhancing PDC efficiency.Key Performance Indicators (KPIs) for PDC EfficacyVarious KPIs have been proposed to evaluate PDC performance.

1.1 These KPIs can be broadly categorized into three main groups:

Technical KPIs: These KPIs measure the reliability and quality of electricity supply, such as the system average interruption duration index (SAIDI), customer minutes lost (CML), and voltage quality indices.
Financial KPIs: These KPIs assess the financial health and efficiency of PDCs, including revenue collection efficiency, operating expenses, and net profit margin.
Operational KPIs: These KPIs measure the operational efficiency of PDCs, such as feeder loss rate, transformer utilization factor, and energy efficiency.

1.2 Factors Influencing PDC Performance

1.2.1 PDC performance is influenced by various factors, including:

Infrastructure: The age, condition, and capacity of electricity distribution infrastructure significantly impact PDC performance. Aging infrastructure can lead to increased losses, reliability issues, and higher maintenance costs.
Demand patterns: Fluctuations in electricity demand can challenge PDCs in maintaining a stable and reliable supply. Unforeseen demand surges can strain infrastructure and lead to outages.
Regulatory framework: The regulatory framework governing PDCs can influence their investment decisions, operational efficiency, and financial performance. Clear and supportive regulations can encourage PDCs to adopt modern technologies and improve their services.
Technology adoption: The adoption of advanced technologies, such as smart grids and intelligent metering systems, can significantly enhance PDC efficiency, reliability, and customer service.

1.2.2 Strategies for Enhancing PDC Efficacy

Several strategies can be implemented to improve PDC performance, including:

Infrastructure modernization: Upgrading and replacing aging infrastructure with modern and efficient technologies can reduce losses, improve reliability, and lower maintenance costs.

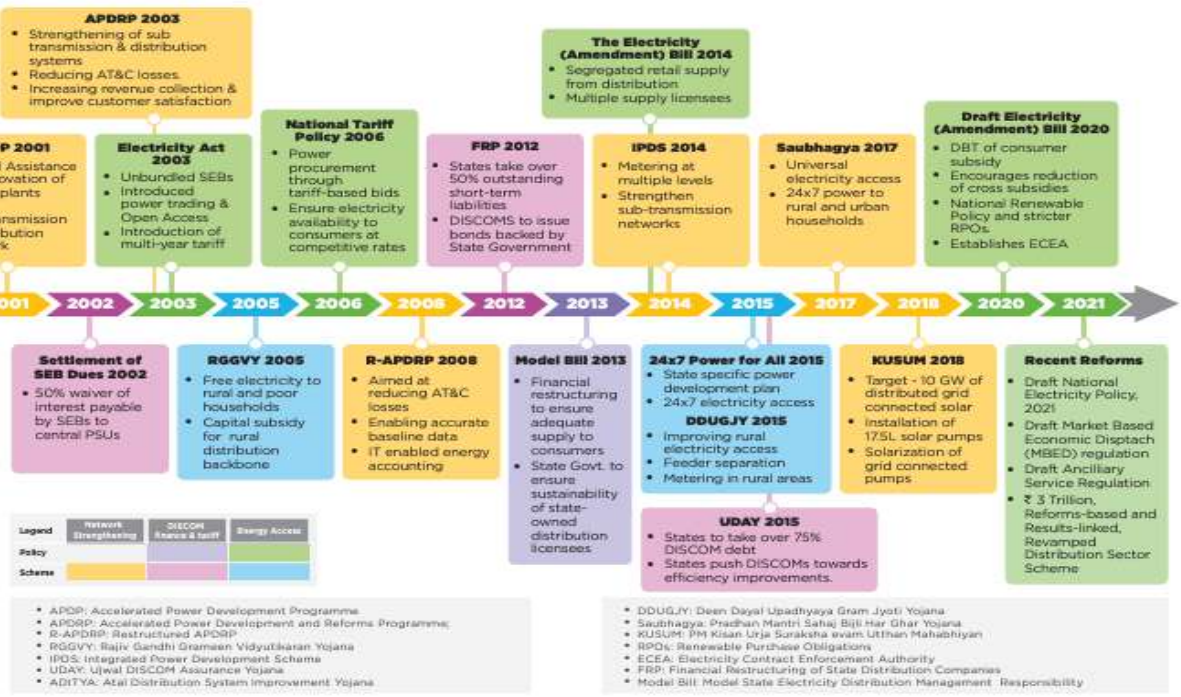
Demand-side management (DSM): Implementing DSM programs can help flatten demand curves, reduce peak demand, and optimize resource utilization.

Smart grid deployment: Smart grids enable real-time monitoring and control of electricity distribution, allowing PDCs to optimize operations, detect faults quickly, and improve resilience against disruptions.

Performance benchmarking: Regularly benchmarking PDC performance against industry standards and best practices can identify areas for improvement and drive continuous improvement.

1.3 Journey of Distribution Sector Reform in India

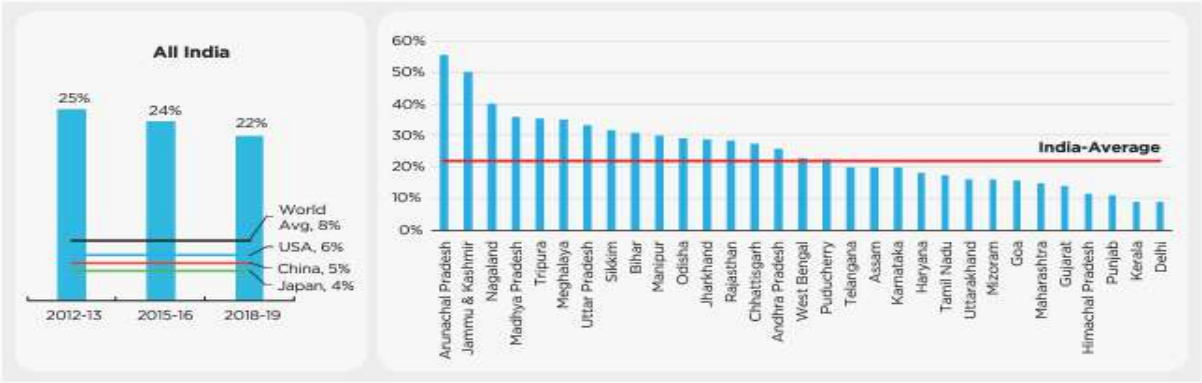
Graph-1



Over the past 20 years, India's power sector has been gradually moving toward liberalization and competition. Numerous attempts to establish competition through market reform and sporadic assistance through large-scale initiatives and infrastructure development have been made throughout the history of the energy industry (Graph-1). The Center has played a critical role in providing financial support, front-loaded infrastructure projects, and policy direction at the macro level (Sources**:** www.niti.gov.in).

1.4 National and State-wise AT&C Losses For 2018-19

Graph-2



Metering, billing, and collection is essential to the profitability of discounts. Overall, nationwide AT&C losses have been steadily declining as a result of ongoing improvements in billing and collection efficiency (Graph -2). AT&C's overall loss has decreased to 22%. On the other hand, losses remain significant when compared globally, and considerable work remains. Even within the nation, state performance varies greatly from one another(Sources**:** **www.niti.gov.in**).

II. REVIEW OF RELATED LITERATURE

Arun, T. G., & Nixson, F. I. (1998) Reviewing recent reforms to the power industry, the article focuses on State Electricity Boards' (SEBs') subpar performance. It emphasizes how crucial it is for state governments to comprehend important issues and perceive their involvement in them.

Baijal, P. (1999),The reform of India's power sector is discussed in the paper, with an emphasis on the benefits of competition from an economic and competitive standpoint. The federal-level reforms, regulatory commissions, and distinct transmission and power-related activities are highlighted. The report also looks at the sector's future intentions and its current state of transformation.

Bhattacharyya, S. C. (1994), Since independence, India's power sector has expanded dramatically; but, unless improvements are made, supply will not be able to meet demand, leading to ongoing power outages.

Das, A., & Parikh, J. (2000),State energy boards, or SEBs, are losing a lot of money; from 1997 to 1998, they lost an estimated Rs 10,684 crore annually. A case study indicates that the financial situation might be strengthened by raising tariffs, reorganizing capital, and enhancing technical performance.

Pillai, N. V., & Kannan, K. P. (2000). Originally founded on social-democratic ideals, India's power development policy was subsequently subservient to socio-economic goals as the State Electricity Boards (SEBs) became government agencies. Technical, institutional, organizational, and budgetary inefficiencies resulted from this. The power industry underwent changes and reorganization in the 1990s as a result of the ensuing budgetary crisis. However, the costs of inefficiency associated with forcing SEBs to function have received little attention. According to a study, the avoidable cost of inefficiency accounted for around one-third of India's estimated energy supply costs between 1997 and 1998.

Kannan, K. P., & Pillai, N. V. (2001). The inefficiency costs of State Electricity Boards (SEBs) in India are discussed in this article with particular attention to supply costs, tariffs, revenue, technical and organizational losses, physical performance, and technical inefficiency.

Kannan, K. P., & Pillai, N. V. (2001). To guarantee social security, India's power development policy established State Electricity Boards (SEBs) to function as state governments. The technological efficiency, losses, and institutional inefficiencies of SEB operations are the main topics of this article's analysis of inefficiency costs. Supply costs, tariffs, income, and financial performance are all covered in Part II.

Kale, S. S. (2004). Since 1947, India's energy sector has experienced two significant policy shifts. Public utilities were founded in the 1950s, and private players were forced to enter the market in the early 1990s. The global economic philosophy and the interests of dominating groups in India were the driving forces behind this change. The change was opposed by state officials and agricultural organizations, while industrialists backed the new agreement. The Electricity Act of 2003 is the result of policy actions spearheaded by the central government to strengthen market strategies and private ownership.

Sharma, D. P., Nair, P. C., et al. (2005),The Indian government began a restructuring exercise in 1991 as a result of the sector's functional problems over the previous few decades. This study examines the sector's performance between 1991 and 2001, assessing how well it accomplished goals and suggesting changes for the future. It also assesses the approach and procedures used.

Bajaj, H. L., & Sharma, D. (2006, December), India started reforming its power system in 1991 in response to growing subsidies, persistent capacity and energy shortages, and economic losses. The goal of the

government was to turn this industry into a productive business. Several states have attempted to adopt the reforms, such as the Electricity Act of 2003, with differing degrees of success. The performance of the Indian electricity industry over the last 1.5 years is reviewed, and the efficacy of the reform process in accomplishing its goals and advancing the interests of the country is investigated.

Bhattacharyya, S. C. (2007), For more than ten years, India's power sector reform has been stuck, and although there is a legal framework in place, liberalization and privatization have not advanced very far. The sustainability of the reform model and its implementation are analyzed in the article, with particular attention paid to political unpredictability, subpar financial results, and possible adverse environmental effects. It demands the use of alternative policies to deal with these problems and guarantee long-lasting changes.

Sharma, A. K., & Vohra, E. (2008),The risks involved, the length of gestation, and the high expenses of infrastructure construction make it difficult. It is difficult for private investors to raise money in time for a project's completion. One debt-free financing tool that can affect a nation's imports, exports, capital reserves, factor endowments, and trade conditions is foreign direct investment (FDI). Infrastructure services FDI has surged in emerging nations; in 2006, it accounted for 22% of worldwide cross-border M&A. The Planning Commission of India emphasized the role of the private sector in infrastructure creation and upkeep, hence facilitating the entry of both domestic and foreign entities into state-owned services. However, there is a significant disparity in foreign direct investment (FDI) throughout India's subsectors; the majority of FDI goes into the telecoms industry, while very little is invested in critical industries like power.

Nouni, M. R., Mullick, S. C., et al. (2008). According to the study, decentralized electricity generation options based on renewable energy, such as photovoltaics, dual fuel biomass gasifier systems, micro-hydro, small wind electric generators, and grid extension, may be more cost-effective than extending the electrical grid in India's remote areas. The load factor and peak load have an impact on the cost of producing and transmitting power.

Nouni, M. R., Mullick, et al. (2009) The study pinpoints specific regions in India where decentralized generation choices based on renewable energy are more economically viable than expanding the system to provide electricity. Depending on the peak electrical load and load factor, the cost of distributing energy in remote places might range from Rs. 3.18/kWh to Rs. 231.14/kWh. It is advised to use solar, dual-fuel biomass gasifiers, and micro-hydro systems.

Purohit, I., & Purohit, P. (2010), India's Jawaharlal Nehru National Solar Mission (JNNSM) seeks to level the playing field between solar and fossil fuel energy sources. The plan intends to do the following: attain 15 million m2 of solar thermal collector areas; develop a regulatory framework for 20,000 MW of solar electricity by 2022; support off-grid applications; and install 20 million solar illumination systems for rural areas. The deployment of concentrating solar power (CSP) technology makes financial sense in the northwest of the nation, especially in the states of Rajasthan and Gujarat, according to a study evaluating CSP technologies in India. The findings may be useful in identifying India's solar energy specialized markets.

Totare, N. P., & Pandit, S. (2010)In 1990, the Indian power sector experienced its first reforms as a result of declining efficiency and financial constraints. In 2005, the Maharashtra State Electricity Board (MSEB) split into four separate firms as part of its restructuring initiative. The reforms, the action plan, the situation following the reforms, the energy supply model, the multi-year tariff plan, new projects, and other states' reform experiences are all covered in this essay.

Singh, A. (2010) To unbundle vertically integrated State Electricity Boards, the Indian power sector undertook the first changes. Through its treatment of topics such as open access, power exchanges, and transmission allocation, the Electricity Act of 2003 advanced the reform process. In addition to reviewing open access initiatives, the paper addresses lingering concerns regarding wholesale and retail competition, such as demand response, supplier of last resort, unbundling retail pricing, liberalization of fuel markets, and market monitoring.

Saxena, S., & Thakur, T. (2011) Although the generation and transmission systems in the Indian power sector are highly advanced, the distribution system is not up to par. Power entities have been restructured in the post-EA 2003 era, and evaluating the distribution sector's performance is essential to determining the effectiveness of reform initiatives. This study, which covers all states and regions in India since March 31, 2008, measures technical efficiency in the power distribution sector using data envelopment analysis.

Yadav, V. K., et al. (2011),Using input-oriented data envelope analysis, the study assesses the performance of 29 electricity distribution divisions in Uttarakhand (DEA). The performance is not at its best, which suggests cutting expenses and staff. The paper proposes to use benchmark share metric to rank efficient units as benchmarks for inefficient ones. It has been discovered that plain area divisions are more effective and have a greater capacity to impact ineffective EDDs. Policymakers and management may find the data useful in boosting operational effectiveness and competitiveness in the Indian electrical industry.

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effectiveness of reform initiatives. This study, which covers all states and regions in India since March 31, 2008, measures technical efficiency in the power distribution sector using data envelopment analysis.

Panda, A., & Patel, A. (2011) India's economic progress is hampered by persistent electrical energy shortages and business losses brought on by inefficiency. 1991 saw the start of government reforms aimed at reviving the industry. These problems and their effects on the Indian energy sector are addressed under the Energy Act, of 2003. The function of the regulator, open access, power markets, power trading, and the Appellate Tribunal for Electricity's involvement in harmonizing regulator orders are all covered in the article.

Ghosh, S. (2012)This report assesses the power distribution sector in India with an emphasis on efficiency enhancement and loss mitigation. It gives information to energy planners and managers, identifies losses that are technical and non-technical, and recommends corrective actions.

Aggarwal, D. P. (2013) This study investigates the profitability of sustainable businesses, a subject that is important to socially responsible investing despite conflicting findings from earlier research that was mostly done in rich nations.

Shrimali, G., Nelson, D., et al. (2013). India's ambitious targets for renewable energy arouse investment worries because of high financing costs—which might push up the cost of renewable energy by 24–32% when compared to the U.S.—and loan conditions that drive up expenses by an additional 13–14%. Because of the high cost of debt, policy lessons from the US and Europe might not be applicable. Interest-rate subsidies can lower the total amount of subsidies by 13–16%, indicating to Indian policymakers that they should focus on long-term, low-cost financing and take a cue from China and Brazil's successful initiatives.

Siano, P. (2014), An electrical system that distributes power intelligently and effectively is called the smart grid. Demand response, or DR, lowers peak demand, enhances system reliability, and encourages customer contact. Based on actual industrial case studies and research initiatives, this article provides an overview of DR potentials in smart grids, talking about cutting-edge technology like smart meters, energy controllers, and communication networks.

Sharma, T., & Balachandra, P. (2015) India must ensure quick economic development and climate change adaptation by increasing its power consumption levels in a sustainable manner. Resource limitations, technological and financial limitations, and the way that climate change affects the usage of fossil fuels could prevent this, though. In order to evaluate India's national power grid, a new framework is put out that contrasts it with an imaginary standard. The National Electricity System Sustainability Index (NESSI) for India can be calculated with the aid of this study, which can also help identify sustainability gaps and create intervention targets.

Gaur, V., & Gupta, E. (2016), This study investigates the contribution of governance and socioeconomic factors to the decline in electricity theft in India. The findings indicate that fewer thefts are related to variables including lower levels of corruption, a greater tax-to-GDP ratio, improved efficiency in tax collection, private installed capacity, poverty, literacy, and income.

III. RESEARCH GAP

While the existing literature provides valuable insights into various aspects of India's power sector, there remains a research gap concerning the comprehensive assessment of the socio-economic impact of power sector reforms. The studies reviewed primarily focus on technical efficiency, governance, distribution systems, and renewable energy, but there is limited exploration of the broader economic and social implications of these reforms. Specifically, there is a need for research that investigates how power sector reforms have influenced employment patterns, income distribution, and overall economic development at the regional and national levels. Understanding the broader socio-economic consequences of power sector reforms will contribute to a more holistic assessment of their effectiveness and inform future policy decisions.

IV. CONCLUSION

This comprehensive review of selected papers on the efficacy of Power Distribution Companies (PDCs) provides valuable insights into the complex dynamics of the electricity distribution sector. The findings underscore the multifaceted nature of factors influencing the performance of PDCs and highlight key areas for improvement. The identified Key Performance Indicators (KPIs), spanning technical, financial, and operational dimensions, offer a robust framework for assessing PDC efficacy. Technical KPIs, such as SAIDI, CML, and voltage quality indices, shed light on the reliability and quality of electricity supply. Financial KPIs, including revenue collection efficiency and net profit margin, provide crucial insights into the financial health of PDCs. Operational KPIs, such as feeder loss rate and energy efficiency, gauge the operational efficiency of these entities. The review emphasizes the pivotal role of infrastructure, demand patterns, regulatory frameworks, and technology adoption in shaping PDC performance. The age and condition of distribution infrastructure emerge as critical determinants, necessitating a focus on modernization to reduce losses and enhance reliability. The

influence of demand fluctuations underscores the need for effective demand-side management strategies. Moreover, the regulatory environment is crucial, with clear and supportive regulations incentivizing PDCs to adopt modern technologies and improve services. Strategies for enhancing PDC efficacy, such as infrastructure modernization, demand-side management, and smart grid deployment, provide actionable pathways for improvement. These strategies align with the broader trends observed in the reform journey of the distribution sector in India, where efforts have been made to introduce competition, improve efficiency, and address financial challenges. The review also identifies a research gap, emphasizing the need for a more comprehensive assessment of the socio-economic impact of power sector reforms. While existing studies focus on technical efficiency, governance, distribution systems, and renewable energy, there is a limited exploration of broader economic and social implications. Future research should delve into how power sector reforms influence employment patterns, income distribution, and overall economic development at regional and national levels, contributing to a more holistic understanding of their effectiveness.

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