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1. Introduction

Energy is the fundamental need of human being for almost all day-to-day activities. Given the scenario of increasing energy demand, it has been a litmus test for the power distribution utilities to operate and manage efficiently and economically, especially in developing nations like India. Various reform processes have been launched and implemented in developing countries, mainly in the east, which faces technical and economic inefficiency along resource crunch (Jamalb, 2006; Singh, 2010). India is no exception to this scenario in addition to being the 3rd highest carbon dioxide emitter in the world. The Indian power sector was facing multi-faceted challenges prior to enactment of Electricity Act, 2003. Significant fundamental changes to the structure of the power industry have been evidenced post-enactment of the electricity act in terms of promoting competition within the sector apart from a flexible regulatory regime mainly for tariff determination. Much of the related concern revolves around the production and use of energy in developing countries, especially India since prosperity and economic growth of a country depends mainly on efficient utilization of energy, which is one of the key elements necessary for overall socio-economic development (Hegde and Ramachandra, 2014).

Given this critical issue, a literature survey is crucial to understand the performance of Indian power sector in order to identify the challenges and major reasons for the inefficiency in the electricity sector supply chain. The study is a narrative literature survey of prior studies on the performance of Indian power sector, post-implementation of Electricity Act, 2003 with an objective to identify the most prominent and widely used methodology in performance evaluation of power sector in India. The authors believe that this study is the first of its kind to perform a literature survey focusing on the performance of India’s power sector emphasizing on the methodologies adopted. The study attempts to identify the major trends in India’s power sector and briefly discusses the current scenario and various key challenges of different segments of the power sector. More importantly, the study classified various studies according to methodologies
adopted in performance evaluation studies in Indian power sector.

2. Research Method

As part of the systematic review, an extensive literature search was performed using scholarly databases such as IEEE Xplore, EBSCO, ProQuest, ScienceDirect, Emerald, Web of Science, Scopus, JGate, and Google Scholar apart from generic Google search engine. Subsequently, published articles related to the performance of power sector in India, post-implementation of Electricity Act 2003 were examined. Following the survey methodology of McCaughey (2012), the articles were searched and identified based on a specific combination of keywords, screened and selected for detailed review based on inclusion criteria of their relevance to Indian power sector performance study and evaluation. Finally, articles pertaining to India’s power sector performance assessment and assessment were selected and reviewed in depth.

3. Review of Literature

Through literature review, different themes of study post-enactment of Electricity Act, 2003 based on methodologies (Dudenhefer, 2009) were identified and tabulated under various categories for different segment wise viz., the power sector in general, generation and transmission, and distribution segment.

**Power Sector in General**

Among the different models of operation available, Transmission System Operator model was suggested by Singh and Srivastava (2004), which will thus enable operation as well as the ownership of the grid to be integrated into a single unit responsible for transmission network development thus offering undiscriminated open access of power to all market participants. The study of Khurana and Banerjee (2015) focused on efficiency and productivity of various segments of power sector value chain regarding financial and operational performance and developed a performance index using Analytical Hierarchy Process (AHP) method. Yadav et al. (2009) performed an inter-country comparative performance evaluation of 19 developing countries including India and showed that India ranked 7th out of 19 countries studied, and the results highlighted the need for good management practices. Malik et al. (2012) examined the impact and operation efficiency due to unbundling of generation segment, and the results of the study showed that unbundling of companies lead to improvement of plant availability by around 4.6% and reduced forced outages by around 2.9%.

1. **AHP** – Analytical Hierarchy Process is a multi-criteria decision-making model developed by Saaty(1977)
Generation Segment

Shanmugam and Kulshreshtha (2015) measured technical efficiency of thermal power plants using the SFA\textsuperscript{2} methodology and showed that western region is more efficient when compared with another region. The maiden study on thermal power plants in India’s Power sector using DEA\textsuperscript{3} was made by Nag (2006). In terms of productivity, Behera et al. (2011) studied thermal power plants focusing on the impact of productivity due to capacity addition. Whereas, Shrivastava et al. (2012) discussed the problem of shortage of available capacity due to insufficient generating capacity additions. In performance efficiency evaluation using DEA methodology for Indian power sector, the concept of sustainability and climate change mitigation imperatives was first discussed by Vazhayil & Balasubramanian (2012). Singh et al. (2013) adopted DEA based MPI\textsuperscript{4} approach to study the productivity change in Indian coal-fired electricity generation to estimate total factor productivity (TFP). A comparative study of the performance of private and public generation companies in India, the first of its kind in India, was performed by Vyas (2015). In hydropower generation segment, the only identified study was of Thakur and Jain (2009) who evaluated the efficiency of 34 hydropower plants and identified few inefficient power plants for improvement.

Distribution Segment

Thakur (2005) made the maiden study to assess the performance of utilities and benchmark in the context using DEA approach. For the same sample utilities, Thakur (2006) made one more maiden study on productivity analysis of state-operated electric utilities by calculating MPI. Further to that, Meenakumari et al. (2010) studied the productivity improvement of state-owned utilities and identified that only 60\% of the utilities have productivity growth. In another extended study, Meenakumari and Kamaraj (2008) adopted correlation and regression analysis, the first of its kind in India, to examine the isotonicity of the variables under study, through which only positively correlated input and output variables are selected for the study. Similarly, Jain et al. (2010) studied utilities with respect to cost parameters including operations and maintenance, administrative and general cost as input parameters for measuring performance efficiency and suggested for unbundling of utilities for better performance. Yadav et al. (2013) studied the distribution companies of Uttarakhand with consideration on the terrain of the distribution areas and performed sensitivity analysis using reliability indices and suggested restructuring as a possible solution for performance improvement. Pargal & Banerjee (2014) discussed the substantial mounting losses in PDUs and estimated that the losses constituted about 17\% of India’s gross fiscal deficit and 1 percent of GDP.

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\textsuperscript{2} SFA - a parametric method that estimates most efficient frontier and gives efficiency scores considering the stochastic error terms (2015)

\textsuperscript{3} DEA - is a non-parametric mathematical linear programming technique used for relative performance efficiency measurement. (1998)

\textsuperscript{4} MPI – is a productivity measurement approach based on DEA methodology developed by Caves, Christensen and Diewert (2010)
Saxena et al. (2015) made the maiden study on National Stock Exchange (NSE) listed companies in Oil, Gas & Power sector and attempted to benchmark inefficient units and targets were suggested to improve performance efficiency of 24 listed companies.

A more comprehensive performance evaluation Integrated Rating methodology (IRM) was introduced by Ministry of Power in 2013. It serves as a mechanism for incentivizing or dis-incentivizing the PDUs to improve overall operational and financial performance. The methodology covers many parameters classified as operational, reforms, regulatory and financial (MoP, 2017).

4. Findings & Discussion

Khetrapal and Thakur (2014) compared various methodologies and identified DEA, SFA, and MPI to the significant methodologies adopted in performance evaluation. In addition to that, our study identified three other methodologies viz. descriptive, AHP and IRM based studies for performance evaluation of power sector in India. Descriptive statistical analysis as shown in Figure 1 indicates that the most widely adopted methodology applied in performance evaluation of power sector in India is DEA, which is confirming with the global trend (Liu et al., 2013; Sueyoshi et al., 2016) witnessing higher growth momentum on the application of DEA in energy sector, particularly electricity industry (Abbott, 2005; Jamasb and Plitt, 2001).

According to Zhu et al. (2008), among the available wide variety of modeling techniques, DEA is a relatively new non-parametric method for performance efficiency evaluation that has got very much attention in recent times. DEA is an operation research-based non-parametric method that uses mathematical linear programming technique for relative performance efficiency measurement of decision-making units (DMUs) that are characterized by multiple inputs and outputs and provides a single measure of performance (Dhontu and Yoo, 1998). Banker, Charnes, and Cooper developed BCC model (1984) with a variable return to scale assumption and proposed DEA model as given below.
\[ \theta^* = \min \theta \]

\text{subject to}

\[ \sum_{j=1}^{n} \lambda_j x_{i0} \leq \theta x_{i0} ; i = 1, 2, \ldots m; \]

\[ \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0} ; r = 1, 2, \ldots s; \]

\[ \sum_{j=1}^{n} \lambda_j = 1, \]

\[ \lambda_j \geq 0 , j = 1, 2, \ldots n. \]

Figure 2 shows a bimodal cyclic trend of the number of studies followed, with modal value as 6 in 2006 and 2010, however, the same did not peak in 2014 as expected in the cycle. Thereafter, the studies have been declining. However, the problems have not been entirely solved yet. Further, the majority of studies have been in distribution segment due to the very evident reason that distribution segment is the one facing a significant challenge in power sector value chain and having an unsolved persistent operation and financial problems.

![Figure 2: Year Wise Number of Studies (Source: Self-compiled)](image)

### 5. Conclusion

Power supply and distribution segment of the power sector is a very vital link in the electricity supply chain as it provides the last mile connectivity to all the consumers in addition to generating revenue in the power sector value chain. Therefore, the critical component which is vital for sustainable future is the distribution of power. Over the last two decades, the electricity industry has undergone various structural and regulatory changes like unbundling of state entities, the creation of independent regulatory bodies and implementation of
reforms to improve the performance of power distribution utilities in India. However, the progress in the performance of the distribution utilities has been the dominant concern for years and continuing (Khurana and Banerjee, 2015). Consultants, advisors, practitioner, as well as academicians, make a note of this and focus on enhancing the studies on distribution segment and bring out strategic solutions for the overall turnaround of the distribution segment. As a way forward, strategic due diligence and more strict reforms need to be implemented to turn-around the ailing distribution sector. Thus, based on the review, it can be concluded that there is an urgent need to bring-forth effective and efficient policy reforms and regulatory frameworks through further extensive research and consultancy on power distribution utilities for the operational and financial turnaround of distribution sector, especially adopting DEA methodology. Since the study was limited to the literature available in selected online databases, there could be other unexplored articles which can be taken up for future research in power sector performance.

References


