SYNOPSIS

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Degree: **Ph.D.** Department: **Electrical Engineering**

Thesis Title: **The Electricity Consumption Trend in The Backdrop of Demand Side Management**

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Month and year of thesis submission: **May 2019**.

Power sector reforms, optimal use of scarce natural resources, green house gasses, black-outs, power failures and load shedding are the tinkling words related to power sector. Due to the bulky nature of capital and time consuming infrastructure development for executing the supply side measures / strategies, the feasible option is to formulate demand side measures in short run to deal with demand rise instead of going for load curtailment [1]. Though various Demand Side Management action plans have been listed by Bureau of Energy Efficiency [2], lower end consumers still face load curtailment as a final measure of demand-supply balance mechanism in case of supply scarcity. This results into sub-optimal allocation / utilization of vital energy resources.

For the implementation of Demand Side Management measures, load research has been identified as one of the key activities of Demand Side Management Cell by [3] and the guidelines of execution process have been

elaborated there-in. The need of proposing Time-of-Use / Time-of-Day tariff to Low Tension (LT) and Residential consumers has been highlighted in the study reports by Forum-of-Regulators with the prerequisite that consumption pattern of identified consumers are needed to be studied for integrating Demand Side Management in power sector [4]. Moreover, to judge the willingness / possibility of load shift, price elasticity analysis is also recommended in [4].

India's electricity consumption has grown by 7.3% per annum since independence [5]. The State Electricity Boards were unable to meet the targeted Rate-of-Return and were forced to rely upon cross subsidies [5]. The generation sector also missed the targets and the increased burden of cross subsidies on industrial consumers accelerated the process of captive generation. Till the late 80's and early 90's, it was realized that the mere privatization of generation will not help the State Electricity Boards to come out from economic failure. So the wave of structural reforms floated along with the World Bank support. The Electricity Act 1910 and the Electricity supply Act 1948 were revoked with a new act called as Electricity Act 2003 [5]. The primary objectives of the said Act are to provide the best possible quality and reliability of electricity supply to the consumers and development of power industry by promoting competitive market environment, proposing rationalized tariff system, transparency in subsidy policies etc [7].

Concept behind Open Access is to provide reliable and quality power supply by offering competitive environment in energy market and giving freedom to the consumers to select the energy supplier by the way of short-term, medium-term and long-term contracts [6]. Open Access by the way of intra and inter-state power purchases have become the way of balancing surplus and scarcity of electricity. But it is limited to high end consumers

only due to connected load criterion of 1 MW. With the goal to improve grid performance, Unscheduled Interchange (UI) of electricity under the Availability Based Tariff mechanism is another way of power purchase under the short term period. But due to Northern grid collapse in 2012, the Deviation Settlement Mechanism [8] came in existence for power transfer using Unscheduled Interchange and a limit to power drawal and injection was levied with heavy penalty upon violation of the limit. Hence, energy trading remains the only option for Open Access and day-ahead basis transactions are most popular rather than real-time like Unscheduled Interchange mechanism. Due to open market option, high end consumers deviate from Discom supply for availing cheaper electricity. Due to such voyage, utility faces revenue loss [9], [10], [11]. To balance this loss, various Open Access charges levied on consumers which are calculated as per [12]. To enhance market completion it had been proposed under the tariff policy to reduce the cross subsidy surcharge levied on consumers as a part of Open Access charges [13]. Additionally, bringing tariff in line with Cost-of-Service is also one of the feature of tariff policy which brings financial threat to the revenue collection [13]. In this study, it is shown how Open Access is financially beneficial to all the consumers by giving comparative analysis and by showing actual yearly gain of a pharmaceutical industry.

The concept of Demand Side Management (DSM) percolated along with above mentioned reforms to achieve "*Reduction in electricity usage by end consumers from their normal consumption pattern; manually or automatically, in response to high UI charges being incurred by the state due to over drawal by the state at low frequency or in response to the congestion charges being incurred by the state for creating transmission congestion or for alleviating a system contingency for which such consumers could be given a*

financial incentive or lower tariff" [14]-[15]. In view of the above, in [17] simulation studies have been presented to flatten the load profiles using standard demand function. Except [18]-[19], other technical papers have incorporated readily available price elasticity matrix or set the co-efficients with little modification. Such modification is difficult to justify considering the fact that depending upon socio-economical background of the country / region / area under study, electricity consumption pattern varies. It is needed to estimate consumer specific price dependency to carry out load profile studies and evolve methodologies for sectoral reforms. In India, Demand Side Management concept has been highlighted by Indira Gandhi Institute of Development and Research (IGIDR), Mumbai in 1991 [20]. By the efforts of Bureau of Electricity Efficiency, utility and area specific Demand Side Management activities are in progression [2]. The Gazette of Gujarat has passed Demand Side Management regulations formed by Gujarat Electricity Regulatory Commission (GERC) in 2012 and as per the guidelines, Demand Side Management Cell has been formed. Load research has been highlighted as the key activity of the Demand Side Management Cell and Demand Side Management implementation guidelines have been mentioned in [21].

From the consumers' point of view, the willingness to respond to reforms will be present only if they have to pay less for the same or more consumption and the initial installation cost for availing the said reforms is recovered in a short span. The concept of load shifting or reshuffling from the normal consumption pattern as a Demand Side Management measure is difficult to achieve under the existing structure without knowing willingness of consumers. Hence, an endevour is made, though at very preliminary stage, to find price elasticity of consumers of all the Distribution companies of Gujarat sector using the data fetched from Regulatory Information Management re-

ports [23]. Regression analysis is the process using which point elasticity is evaluated.

For the purpose of load profile study, understanding of consumption pattern of consumer categories is necessary. If more the sub-categorical data available, better is the load profile study possible. Such study may be useful in deciding Real Time Pricing / dynamic pricing / Time block wise electricity rates etc making available to maximum possible consumer categories. The suggested method, till date, for sub-categorization or formulation of new consumer categories based on consumption pattern is the clustering of load shapes [25]. Hence, a trial has been made to cluster feeders having similar load patterns using DNHPDCL feeder level electricity consumption data. Self Organizing Map and K-means algorithms have been utilized in the process of clustering.

To evaluate the effectiveness of Time-of-Use tariff structure, optimization problem is formed to maximize the night rebate when certain mount of peak load of a continuous process industry is shifted to night hours within certain constraints like maximum demand, mandatory Open Access drawal etc. Evolutionary optimization technique is used based on the nature of the mathematical formulation.

For improvising Distribution company's (Discom's) financial performance, the tariff rise or increase in subsidy have been projected [22]. Under the Electricity Act 2003 and National Tariff policy 2006 [13], tariff rationalization has been projected by aligning it to the average service cost. Subsidy provision is burden on state government and tariff rise is burden on the non-subsidized group of consumers. Participation of non-subsidized consumers into energy market due to provision of Open Access creates cross-subsidy loss at Discom end. Hence, for the overall improvement in the performance of a Discom,

tariff rationalization is required to be focused at. Hence, an endevour is made to reduce the subsidy burden on the consumers by modifying a basic model presented by Forum of regulators [24] where the gap between cost of service and Tariff is tried to reduce. The objective set is to provide financial gain to distribution company while setting a restriction on tariff rise. Two methods namely Sequential Quadratic Programming and Iterative Techniques are used for the analysis.

Thus, the study falls under the category of Techno-Economical analysis with the major objectives categorized as:

- Estimating price dependency of consumption
- To understand electricity consumption trends of major feeders (or consumer categories) contributing to load shape of utility (Discom) i.e. peaking effects, seasonal shifts.
- Endevor to propose rationalized tariff structure to ensure the Discom as a no-loss making entity. Prior to achieve the said, it is necessary to
    1. understand existing Tariff structure
    2. understand the Open Access scenario in energy trading
    3. reduce the gap between Cost-of-Service and Tariff offered or more precisely the Average Billing Rate

In the view of the above, thesis is structured into following chapters.

The **chapter-1** portrays Indian power sector reformation in brief. It also highlights the major points from which the study herein is motivated.

In **chapter-2**, basics of Demand Side Management are highlighted and the concept of Price Elasticity is presented in detail. With the available data

of five Discoms, point elasticity results are evaluated and presented therein. The chapter also describes the lack of system infrastructure and futuristic needs to implement the Demand Response concept as a part of Demand Side Management in Indian power sector.

Chapter-3 presents the Open Access concept and describes the short term OA in detail which is available only to the Industrial category consumers in the prevailing regime. By comparative results, it is shown how this concept is and will be benefited to the consumers if percolated further and will be helpful in paving path for rationalized tariff structure with the proposed phase-wise policy implementations.

Chapter-4 presents the results of feeder level clustering of Dadara Nagar Haweli Power Distribution Corporation Limited (DNHPDCL). The results obtained by comparison of two clustering techniques namely Self Organizing Maps (SOM) and k-means algorithm.

In **chapter-5** Time-of-Use tariff structure of Gujarat state has been presented. Using the billing information of a continuous process industry, it is predicted that with certain load shift from peak and non-peak hours to night hours, considerable financial gain can be achieved by the consumer.

Chapter-6 deals with cross subsidy component present in tariff. Two different approaches incorporating Universal Charge concept have been tested to bring the tariff of electricity in line with the Cost-of-Service. The tariff policy guidelines are considered as constraints to limit the tariff rise. Six major consumer categories whose tariff and consumption records are readily available with Gujarat Electricity Regularity Commission are considered for analysis. Results are practically acceptable as the gap between Cost-of-Service and tariff is narrowed and the distribution company also gains profit even though there is reduction in cross subsidy due to constraints set on

tariff rise.

In **Chapter-7**, main findings of the thesis have been summarized and future scope has been presented.

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List of Publications

Based on the work described in Thesis (Presented/Published in National/International Conference/Symposiums/ Journals and Indexed in Databases)

- Journal:

    1. Varada J. Tambe, S. K. Joshi, *"Estimating Price Elasticity of Electricity for the major consumer categories of Gujarat state"*,

Journal of Electrical Engineering, vol. 15, no. 1, pp. 367-374, 2015 (ISSN : 1582-4594)

- Book Publication:

  1. Varada J. Tambe, S. K. Joshi., *"Constraint Tariff model to reduce the amount of Cross Subsidy incorporated in Electricity Tariff using iterative optimization technique"*, Proceedings of ICTSES 2018, Springer Lecture Notes in Electrical Engineering, vol 607, (ISBN 978-981-15-0214-9 (eBook))

- Conference: Papers are published in proceedings.

  1. Varada J. Tambe, S. K. Joshi, *"Estimation of Price Elasticity of Electricity to evolve a methodology for implementing load management programs at Discom level, in India"*, RTEECE-2014, India, pp. 115-120, January 2014 (ISSN : 2321-9939)
  2. Varada J. Tambe, S. K. Joshi., *"Highlighting the Open Access Scenario in Electricity Market: Indian Context"*, Indicon, Coimbatore, India, 16-18 December 2018 (Available in proceedings)
  3. Varada J. Tambe, S. K. Joshi., *"Comparison of Clustering Techniques for Electricity Feeder Segregation Based on Load Pattern"*, Indicon, Coimbatore, India, 16-18 December 2018 (Available in proceedings)
  4. Varada J. Tambe, S. K. Joshi, *"Cross Subsidy Reduction from Electricity Tariff while making Distribution company a Profit gaining Entity"*, International Conference On Recent Innovations In Electrical, Electronics & Communication Engineering (ICRIEECE),

Bhubneswar, India, 27 & 28 July 2018 (CFP18P98-PRJ:978-1-5386-5994-6)

5. Varada J. Tambe, S. K. Joshi, *"Increasing the Effectiveness of Time of Use Pricing using Optimization Technique: A case study of HT Industry in Gujarat"*, International Conference On Recent Innovations In Electrical, Electronics & Communication Engineering (ICRIEECE), Bhubneswar, India, 27 & 28 July 2018 (CFP18P98-PRJ:978-1-5386-5994-6)