Chapter 1

Introduction

1.1 General

India's per capita electricity consumption has grown by 7.3% per annum since independence [1]. The State Electricity Boards (SEB) were unable to meet the targeted Rate of Return and were forced to rely upon cross subsidies [1], [2]. 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 SEBs 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. 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 electricity industry by promoting competitive market environment, proposing rationalized tariff system, transparency in subsidy policies etc. Steps to bring rationality in tariff structure were proposed under the National Tariff

Policy 2006 by highlighting the presence of cross-subsidy factor [3]. "*According to the Planning Commission, India needs to triple or quadruple its primary energy supply and increase its installed electricity capacity by at least five or six times its 2004 levels to meet demand in 2032. By 2032, India will need a total primary energy supply of approximately 80 million tera-joules, almost triple its 2010 supply of 29 million tera-joules and requiring a compound annual growth rate of 4.7 percent*" is the projection presented in [2]. Due to the bulky nature of capital and time consuming infrastructure development for the supply side measures / strategies, the feasible option to deal with demand in short run is to formulate strategies which concentrate on demand side measures instead of load curtailment [4].

Unscheduled Interchange (UI) of electricity under the Availability Based Tariff (ABT) mechanism was introduced with the goal to improve grid performance [5]. Thereafter, Deviation settlement mechanism [6] came in existence after Northern grid collapse in 2012 due to bulk power transfer on short term basis and a limit to power drawal and injection was levied with heavy penalty upon violation of limit.

Hence, under the restricted regime as stated above, Demand Side Management (DSM) has been identified as an alternative to supply side measure to deal with upcoming rising demands [4]-[7].

1.1.1 Relevant Highlights of Electricity Act 2003

"*To consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, ensuring transparent policies regarding subsidies, promo-*

tion of efficient and environmentally benign policies, constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto" is the purpose of proposing Electricity Act (EA) 2003 [5].

The major highlights regarding Licensing, Transmission, Distribution and Tariff are under the part IV to VII under the following sections.

- Section 42 highlights Open Access.
- It is presented in Section 61 that the Tariff should reflect the prudent, efficient Cost of Supply of electricity and it is recommended to reduce the cross subsidy.
- Section 65 directs the need of giving direct subsidy to poor categories with transparency in allotment.

1.1.2 Relevant Highlights of Tariff Policy 2006

Major highlights of Tariff policy 2006 [3] are:

- The BPL consumers having consumption of 30 units or less are entitled for subsidy support and the applicable tariff should be at least 50% of the average cost of supply. This provision is subject to revision for every 5 years.
- Gradual reduction in Cross Subsidy and bringing the tariffs within ±20% of Average cost of supply.
- Subsidized rates of electricity only up to a pre-identified level of consumption beyond which tariffs reflecting efficient cost of service should be applicable. Concept of direct transfer of subsidy by means of prepaid meters to the needy consumer.

- Tariff for Agricultural sector should be decided based on geographical area i.e. water level. Higher subsidy should be considered only where more electricity is needed for irrigation purpose.
- The surcharge applicable to Open Access consumers should be computed as the difference between i) The tariff applicable to the relevant category of consumers ii) The cost of the distribution licensee to supply electricity to the consumers of the applicable class.
- Bringing down the cross subsidy surcharge linearly to maximum of 20% of its opening level by the end of 2010-11.

1.2 State-of-Art

Electricity is the only commodity which can not be stored in bulk. The supply side measures of infrastructure development for additional generation is a long term process involving to overcome the cost factors, regulatory and other obstacles. Resulting obvious solution to overcome rising demand is load shedding in case of supply scarcity. Hence, the best possible measure to deal with supply shortage in short run is to implement demand side measures. Demand Side Management (DSM) is an action taken to optimize electricity consumption by means of change in electricity usage so as to have collective benefit for utility as well as consumers. Demand Side Management programs consist of the planning, implementing, and monitoring activities of electric utilities which are designed to encourage consumers to modify their level and pattern of electricity usage [8]. Demand Side Management is used in broader sense where various DSM activities like Energy Efficiency (EE), Energy conservation (EC) and Demand Response (DR) depending upon focusing activity have been highlighted in [4] and [9]. In India, Demand Side

Management concept has been highlighted by Indira Gandhi Institute of Development and Research (IGIDR), Mumbai in 1991 [10]. By the efforts of Bureau of Electricity Efficiency (BEE), utility and area specific Demand Side management activities are in progression. 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 [11]. The [12] is a study conducted under the various activities of Bureau of Energy Efficiency (BEE) for implementing Demand Side Management. The residential and commercial establishments in Gujarat were targeted to understand end-use consumption patterns.

Demand side management activities need pre-requisite studies as possibility of load pattern modification based on price variation i.e. estimation of price elasticity, effectiveness of price dependent pre-existing tariff structure, issues of existing tariff structure etc. Hence, various studies pertaining to price elasticity, load profiles of existing consumers, analysis of existing tariff mechanism have been reviewed as follow.

Demand Response (DR) is defined as *"the changes in electric usage by demand-side resources from their normal consumption patterns in response to changes in the price of electricity over time or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized"* i.e. at risk [9]. To evaluate the readiness of demand shift on account of price differential, it has been proposed to analyze price elasticity. Majority of the studies which have estimated price elasticity of electricity consumption are from the field of economics, energy and public policy [13], [14], [15], [16], [17], [18], [19],[20], [21], [22], [23], [24]. Except [23] who developed elasticity formula and [24] who referred [25], majority of other studies dealing with load/demand profile

modification have either "set / assumed" the price elasticity or "modified" the referred values. Reliability of such modifications / assumptions is limited to the simulations only as the factual estimation becomes necessary when it comes to the policy improvisation. This is because of the fact that load profiles of various consumer categories in different demographic areas differ due to the economic growth, tariff structure and availability of substitutes. The studies for estimating Price Elasticity for electricity consumption in Indian context could be listed as [14], [16], [17], [19] and [26]. Estimation of Price Elasticity has been highlighted as one of the key parameter for load profile modification based on tariff structure and for increasing the penetration of Time of Use / Time of Day tariff into the existing consumer categories [27]. The other approach of Demand Response techniques has been considered for isolated environment of microgrids [28], [29] and [30]. [28], [29] have dealt with agent based market creation for implementing Demand response. [30] has considered virtual environment where DC microgrid concept is evaluated for AC load shifts. Consumer benefit oriented approach to flatten the load profile has been considered by [31] but it is restricted to residential category only. ANN based restricted area oriented pricing development technique has been implemented by [32] for DSM implementation. But area load based pricing is just a hypothetical case and this is the limitation of the study. An automatic load control technique which is helpful for Indian scenario has been developed by [33]. [34] focuses the middle income household for load based pricing. This scheme has came-up with better results than Time-of-Use scheme. As the study is targeting residential consumers, the subsidized environment restricts such pricing possibilities.

Under the deregulation environment, study of the continuous load profiles has been identified as the most needed task for promoting Demand Side

Management [7]. Load research / load profile study has been identified as one of the key activities of Demand Side Management Cell by [11], [35] and the guidelines of execution process have been elaborated there-in. Self Organizing Map (SOM) capacity to classify customers using load profiles has been evaluated in [36]. Cascade application of Self Organizing Map based clustering with k-means algorithm has been presented in [37]. Accuracy based assessment of classification tool has been conducted in [38]. The Self Organizing Map based classification technique and follow-the-leader algorithm are compared and based on two performance measures, optimal vector is considered from the generic index vectors for giving sharper discrimination properties in [39]. Simulation of system load profile by integrating various consumer load profiles as per their contribution to system load has been analyzed by [40] to design a new tariff method. Using newly introduced load factor and loss factor terms, variation in feeder consumption for clustered data of a specific zone is tried to identity [41]. The residential and commercial establishments in Gujarat were targeted to understand end-use consumption patterns in a study conducted under the various activities of Bureau of Energy Efficiency (BEE) for implementing Demand Side Management [12].

The concept of Demand Side Management also emphases various tariff mechanism providing incentive, rebate and inflicting penalty also, if needed, to flatten the load profile so as to limit the need of excess electricity during peak hours. One of such proposed pricing mechanism is Time-of-Use (ToU) tariff [42]. Segregating consumers by clustering technique and then designing Time-of-Use in the backdrop of Demand Response has been presented in [43]. Time-of-Use mechanism is suggested for the consumers of low income group category in [44]. Derivation of Time-of-Use as a part of pilot

study for Demand Side Management considering residential consumers has been presented in [45]. Machine or job scheduling based on Time-of-Use is presented in [46]-[47]. Effectiveness of Time-of-Use has been highlighted by [48]-[49] based on surveys or case studies. Almost a decade older Indian scenario has been presented in [50]-[49]. A study was published by the Forum of Regulators (FoR), India to show the impact of Time-of-Use structure in India [51]. It has been tried to introduce modified Time-of-Use technique for newly generated signature load profiles using existing feeders [52].

As the concept behind Open Access is to provide reliable and quality power supply by offering competitive environment in energy market [53]-[54], high end consumers deviate from Discom supply for availing cheaper electricity. Along with the Industrial consumers, one of the biggest consumer of electricity, the Indian railways, has also started withdrawing their huge quantum of load from the utility service and have entered into energy market [55]. Due to such voyage, utility faces revenue loss and to balance this loss, various Open Access charges have been levied on consumers which can been calculated as per [56]. 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 [3].

Bringing tariff in line with cost of service has also been one of the feature of tariff policy which brings financial threat to the revenue collection [3]. For utilities to sustain in the reforming power sector, the tariff methodology and subsidy pattern are needed to be focused at [57]. As far as the international scenario is concerned, tariff in line with marginal cost and transparency in pricing is desired. In the studies pertaining to China [58], Japan [59], Russia [60], Tehran [61]; it is commonly concluded that the Ramsey pricing structure is a good economical option but the hurdle pertaining to its implementation

is existing policies of irrational tariff. Considering the Philippine's case, in cross subsidy reduction process, rules for universal charge method are well defined in the Electric Power Industry Reform Act (EPIRA) [62]. On the same line, Forum of Regulators (FoR), India has published a report to roll out the cross subsidy component by incorporating Universal Charge (UC) in addition to tariff [63].

1.3 Motivation

From the consumers' point of view, the willingness to respond to the Demand Side Management 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 various studies like [28], [29], [30] listed in above section portray the Demand Response techniques for load flattening in isolated environment, simulation studies for virtual energy market etc. They set good study examples but lack in portraying existing Indian power sector scenario. Furthermore, residential consumer category oriented studies like [34] and [31] are less helpful as in India as this sector is subsidized. Subsidy factor does not give clear picture of scarcity cost of electricity. So instead of considering such subsidized categories for Demand Response study, it is better to target the consumer categories paying more than cost of service. 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 load study. The studies carried out for Price Elasticity estimates pertaining India are based on almost a decade older aggregate level data [14], [16], [17], [19], [26]. Over this period, the Indian power sector has undergone a considerable change. In

this background, re-evaluation / re-estimation of Price Elasticity is required prior to insisting for load flattening. Hence, under the structural reformation, the possible responses from the consumers are utilization of energy efficient appliances by taking advantage of government subsidy if available, availing optional pricing schemes like Time-of-Use and availing open access if granted by the utility.

For improving Distribution company's (Discom's) financial performance, the tariff rise or increase in cross-subsidy remains the option [1]. Agricultural Subsidy provision is burden on state government and tariff rise is burden on the non-subsidized group of consumers [3]. Participation of non-subsidized consumers into energy market due to provision of Open Access creates cross-subsidy loss at Discom end [53]. To enhance market completion, it had been proposed under the tariff policy to reduce even the cross-subsidy surcharge levied on Open Access consumers [3]. Hence, for the overall improvement in the performance of a Discom, tariff rationalization is required to be focused on.

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 consumer categories contributing to load shape of utility (Discom) i.e. peaking effects, seasonal shifts.
- Endeavor 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
3. reduce the gap between Cost-of-Service and Tariff or more precisely the Average Billing Rate (ABR)

The thesis starts with introducing power sector reformations like Open Access, Time-of-Use tariff etc resulting into consumer benefits, highlights the necessity of continuous load research and lastly it focuses at utility's financial performance and tries to suggest tariff rationalization by the way of reduction in cross-subsidy present in tariff structure.

1.4 Thesis Organization

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 Open Access in detail which is available only to the high end consumers having consumption ≥ 1 MW. By comparative results, it is shown how this concept is and will be benefited to the consumers 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

are obtained using Self Organizing Maps and k-means clustering techniques.

In **chapter-5**, Time-of-Use tariff structure of Gujarat state has been presented. Using the billing information of a continuous process industry and optimization algorithm, it is predicted that with certain load shifted to night hours, considerable 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 (GERC) 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.